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INTRODUCING THE CONTRIBUTORS

FIRMAN E. BEAR ("Science and Economics in Crop Production") is Professor of Agricultural Chemistry at Rutgers University, New Brunswick, New Jersey, and Soil Chemist of the New Jersey State Agricultural Experiment Station. He was formerly director of agricultural research for the American Cyanamid Company. His article is an interpretation of potentialities for agricultural production, trends in agricultural practices, and problems involved in increasing crop yields. It is a broad picture of the effects of science and technology on crop production and as such is especially pertinent in these times.

JAMES D. TELLER ("Great Teachers of Science: II. Louis Agassiz"), formerly of the College of Education of Ohio State University, has been since 1943 personnel technician with the Adjutant General's Office of the War Department, Classification and Replacement Branch. Long interested in the history and philosophy of science and education, Dr. Teller presents the second of his biographical studies of great science teachers. The first of these, a study of Thomas Henry Huxley, appeared in SCIENCE EDUCATION for December, 1942.

HEBER ELIOT RUMBLE ("A Hundred Years Ago in Science Education at the Junior-High-School Level") offers his paper as a sequel to one which appeared in the March, 1944, issue of this journal. In the earlier article, Dr. Rumble traced the origin of science education at the junior-high-school level back from proposals made in 1876 to colonial days; in the present article, he considers in some detail the teaching of science at this level during the years 1827 to 1857.

CHARLES W. QUAINTANCE ("Oregon Surveys Its Teaching of Elementary School Science") reports on the work of a research committee consisting of himself as chairman, Dr. Wayne W. Wells, Southern Oregon College of Education, Ashland, and Mr. Homer Dodds, Oregon College of Education, Monmouth, assisted by Miss Florence Beardsley, state elementary school supervisor. The committee carried on its work under a grant from the General Research Council of the Oregon State System of Higher Education. Dr. Quaintance is assistant professor of biology at Eastern Oregon College of Education at La Grande.

LOUIS TEICHMAN ("The Ability of Science Students to Make Conclusions") submits a report of his doctoral dissertation, recently completed at New York University. Dr. Teichman, a teacher in the New York City schools, has taken an active part in the advancement of aviation education in high schools, and offers a course in general aeronautics at Teachers College, Columbia University.

HILDEGARDE ROMBERG ("Improving Reading in Elementary Science") prepared her article for publication at the suggestion of a Chicago district superintendent, who heard her present an extended paper on the same topic before a group of Chicago principals. The paper provides a reference list of articles and books on improving reading in science, and should prove valuable to classroom teachers, student teachers, and research workers. Miss Romberg is principal of the Oliver H. Perry School in Chicago.

The symposium ("How Can Science Education Make Its Greatest Contribution in the Post-War Period?") is continued from the October issue. With the statements printed in this number, the symposium, as arranged by PROFESSOR PALMER O. JOHNSON, of the University of Minnesota, is brought to a close. However, if other readers of the journal wish to contribute their ideas on the important topic or to comment on the opinions presented, the editors will be glad to receive their statements.

SCIENCE EDUCATION

VOLUME 28 DECEMBER, 1944 NUMBER 5

SCIENCE AND ECONOMICS IN CROP PRODUCTION

FIRMAN E. BEAR

Rutgers University, New Brunswick, New Jersey

FARMING in the United States is now geared to feeding a considerable part of Europe as well as ourselves. When the war has been won, however, the peoples of all the plundered lands will be motivated by an intense desire to have more and better things to eat and, to that end, they will quickly apply themselves to the task of becoming self-sufficient in food production. As soon as the nitrogen of war is released for peaceful purposes, pressure will be applied to make ever greater use of it as a crop stimulant, both at home and abroad. When this has come to pass, the effects may well be felt far out on the American prairies, and more than the normal number of our farm boys and girls may begin to look about for some more remunerative enterprise than agriculture. Food is important, but only to the point that the human appetite is satisfied. Selling prices of farm products fall sooner and farther after a war is over and tend to stay down longer than those of most other commodities.

THE PRESENT STATUS OF AMERICAN AGRICULTURE

The potentialities for crop production in the United States, when considered both in relation to the total area of land that could be employed for this purpose and the developments in the science of soil management, plant breeding, and parasite control, are enormous. In preparation for their careful study, it would be well to consider first a few facts concerning the present status of farming in this country. Suppose, for the moment, that we imagine ourselves in an airplane, high up over the center of the United States, looking down into the forty-eight states and noting what the many millions of farm folks who are scattered over our nearly two billion acres of land are doing. Let us further suppose that our vision can be made to register the element of time so that we see things both in relation to what they have been and what they are to be.

These are some of the things that should impress us:

Some six million farms that are tending to become fewer in number and larger in size, especially in those areas where modern machinery can be put to highly effective use in industrialized systems of farming.

Some seven million fast-moving farm tractors, trucks, and automobiles that are taking over the jobs of millions of horses, mules, and men, and greatly accelerating the pace on the farm.

Some 345 million acres in harvested crops (1943), as indicated below:

Crop	*Millions of Acres*
Corn	97 *
Wheat	54
Hay	50
Oats	43
Cotton	22
Barley	18
Sorghums	17
Soybeans	15
Flax	6
Peanuts	5
Potatoes	3½
Truck crops	3½
Beans	3
Rye	3
Cowpeas	2½
Rice	1½
Tobacco	1½
Sugar crops	1
Sweet potatoes	1
Peas	¾

* This is equal to the total acreage of land in New York, Pennsylvania, New Jersey, Delaware, Maryland, and Virginia.

Some 200 million domestic animals, as shown below:

Animals	*Millions*
Cattle	78
Sheep	55
Hogs	50
Horses and Mules	15
Goats	4

If we look more closely we shall see:

That the farm population is tending to decrease both percentagely and in actual numbers, having recently fallen from a more-or-less-fixed level of between 30 and 32 million to around 28 million, whereas the population as a whole has been increasing at the rate of about 1 per cent a year. This indicates a marked increase in agricultural efficiency.

That horses and mules are rapidly disappearing from the farm picture, the work-animal population having fallen from 25 million in 1920 to 15 million in 1940. As a result, some 50 million fewer acres are required for hay production and that much more land is available for clean-cultivated crops. Sod crops tend to bind the soil to the earth and, in proportion as they are not required, more difficulty is experienced with soil erosion by wind and water.

That of the 46 million acres of land once devoted to cotton, less than half are now required for this crop, with the possibility that this average may be further greatly reduced after the war. The cotton crop is faced not only by low-cost competitive production in Central and South America but by a rapid growth in the manufacture of synthetic fibers from wood. The net effect is a forced change in the agriculture of the South, part of which may materialize in a greatly enlarged acreage of pine forests, and part in the production of livestock with resulting competition with the farming areas farther north.

That the area devoted to the oil-bearing crops, notably soybeans and peanuts, has grown so rapidly during the last ten years as to add to the uncertainty concerning the outcome of the butter-oleomargarine contest. Previously the competition was between the butterfat of the North and the cottonseed oil of the South, but soybeans, a highly important source of oil that can be used in the production of oleomargarine, are produced both in the North and South.

That the sales of citrus fruits have more than tripled during the last thirty years while those of apples have been cut in half. The Food-Nutrition Board of the National Research Council advise that our pre-war diet was still 28 per cent deficient in citrus fruits and tomatoes.

That the truck-crop acreage has doubled during the last twenty years, with the possibility of considerable further expansion along the Atlantic Seaboard. This is our most intensive type of farming with potentialities both for profit and loss.

That the annual consumption of beef, pork, and mutton has fallen from 163 pounds per person, in 1908, to 125 pounds per person per year, in 1935–1940, whereas the demand for poultry products has continued to increase. We are now consuming around 45,000 million dozen eggs per year.

FARMING OF THE FUTURE

If we project our vision into the future we shall see:

The use of much more than the 30 million tons of lime and fertilizer that are now being applied annually to the land as the necessity for replacing the elements that are being lost from the soil by erosion, leaching, and crop-removal increases. There will be need not only for more tons of the usual lime and fertilizer elements (Ca, Mg, N, P, K, and S) but for an increasing number of trace elements (B, Cu, Mn, Zn, and Mo) as well.

Great improvement in the yield and quality of crop plants as a result of breeding and selection. The yield of corn has been increased by an estimated 15 per cent through the development of hybrids especially adapted to the several corn-growing areas. Similarly, we now have rust-resistant small grains, wilt-resistant alfalfas, and a large number of improved vegetables and fruits that have been selected for their capacity to resist the attacks of insects and diseases, or because of their higher yield or better quality.

Increased efficiency of livestock through better breeding and feeding and by better disease control. Artificial insemination, for example, has made it possible to multiply the usefulness of exceptional sires by 20, and this figure may ultimately be raised to 50 or more.

Marked increase in the use of improved farm machinery adapted for large-scale use in intensive-farming areas. The number of farm tractors increased from the 2,000 experimented with in 1909 and the 200,000 more efficient ones manufactured in 1920 to a total of nearly two million of the fast-moving types that are now in operation in the United States. With the growth in the use of the tractor has come the small-grain combine, the band-fertilizing planter, picker, and field ensilage-cutter for corn, the multirow planter and sprayer for potatoes, the field-chopper, crusher-mower, and pickup baler for hay, and the mechanical picker for cotton.

Great lengthening of rural transmission lines and the use of much more electrical energy on the farm. This permits of the installation of electric lights, pumps, grinders, fences, washing-machines refrigerators, quick-freezing units, and many other types of machinery and conveniences.

Rapid expansion in the use of airplanes for the transportation of fresh farm products to distant centers of consumption the world over. Perishable products can be carried at high altitudes without artificial refrigeration.

Widespread development in air-conditioning, especially in irrigated desert areas, and in the southern states where its rejuvenating effects should aid greatly in overcoming the lethargy that goes with long summers. The extent to which this can be done depends upon the amount of electric energy that can be made available. The construction of dams to control the flood waters is the ultimate answer to this need.

Enlarged conservation programs that are designed to keep the water of excessive rainfall under control, thereby transferring large amounts of land and cultivated crops to hay and pasture, from subsistence farming to forestry, recreational purposes, and game preserves. Corn, tobacco, potatoes, beans, peanuts, pumpkins, and tomatoes, all clean cultivated crops, were entirely unknown to the Old World before the discovery of America. Nearly 140 million acres of our best land was being turned with the plow and planted to these crops and to cotton every year, before anyone realized what disastrous effects they were having on the staying powers of the soil.

INTERRELATIONS OF AGRICULTURE AND INDUSTRY

It seems probable that developments on the better farms will be such as to greatly increase the attractiveness of farm life for aggressive young men and women. The

telephone, radio, televiser, automobile, airplane, tractor, and electric light and power make farming not only a way of living but a means of living well, and permit of the development of farm enterprises of sufficient size to command the interest of the most capable technically trained man.

It is becoming increasingly apparent, however, that with increasing efficiency on the part of those operating the larger acreages of the better land, the smaller farmers may be subjected to ruinous competition in the period of depression in agriculture that may follow within a few years after the war has been won. This is particularly true of those who do not own the land they operate or do not have adequate working capital for their farming enterprise.

It is not possible to divorce agriculture from labor, the world of commerce and industry, and monetary considerations. If we have a period of industrial prosperity, and if labor is fully employed to the extent that the surplus of young farm people continue to go into industry and commerce, then agriculture should also enjoy prosperity. On that basis, an ever-increasing use would be made of improved machinery, acre yields would be raised to higher levels, more land would be brought under cultivation, and the purchasing power of the farmer would be increased, with resulting further benefit not only to agriculture but to industry as well. If, however, industry tends to slow down, and surplus manpower begins to back up on the farm, then farming becomes more and more largely a means of subsistence, particularly on the part of that large group of farmers who have never been far removed from marginal farming, whether because of poor land, inadequate capital, or lack of business acumen. In other words, agriculture cannot stand alone. It must have the support of industry.

But industrial developments are capable of making great changes in agriculture. For example, if powdered milk has anything like the future that some men predict for it, there may be a very large increase in the consumption of milk, and in the need for an enlargement in the dairy industry. It is possible, of course, that such a development might cause serious disturbances to the dairy farmer, particularly if the consumption of fluid milk was greatly reduced.

POTENTIALITIES FOR CROP PRODUCTION

Considering further the potentialities for increased production, it may be worth while to note the major uses to which the total land area of the United States is now being put. These can be summarized as follows:

Use of Land	*Millions of Acres*
Farms	1,054
Forests	378
Public grazing land	182
Indian reserves	55
Parks	17
Wildlife refuges	64
Railroads and highways	24
Cities and towns	10
All other uses	121
	1,905

It will be recalled that only 345 million of the more than one thousand million acres of land in farms are being devoted to harvested crops, the remaining acreage being devoted to pasture or woodland, or lying waste. An additional 50 million acres could probably be put into harvested crops if there was any need for it. Instead, however, there will probably be a reduction in the acreage of cropped land, once the necessary adjustments have been made after the war is won.

According to population specialists, the number of people in the United States will probably increase from the present 135 million to around 160 million, after which it will remain more or less stationary. No very serious problem would appear to be presented in growing adequate amounts of food and fiber for such a population. Not only can the acreage of cropped land be increased, but the yield per acre can be doubled if the necessity arises.

We are still far from attaining the possibilities in crop production. Every farm scientist knows that twice the present average acre yields of crops could readily be produced. In spite of all that science has done for agriculture, our corn yields average only about 25 to 30 bushels, our wheat yields, 13 to 15 bushels, our potato yields, 100 to 120 bushels, and our cotton yields 160 to 200 pounds of lint. Acre yields of over five times these amounts have been recorded.

But it must be remembered that farming cannot be carried out with the exacitude that the manufacturer is able to attain. Crops and livestock are living things that are subject to disease, insect and mechanical injury, and the effects of the weather. Furthermore, plowed land is subject to serious losses of soil by erosion. The most troublesome problem involved in such erosion is that of the ruination of the contour of the land, as a result of which it is broken up into smaller and smaller areas that cannot readily be farmed with large machinery.

One must also face the fact that an estimated one-third of our country people are subsistence farmers, having little or no desire to produce more than they consume. They are not necessarily any less efficient than the lower one-third in any other line of endeavor. They are, however, easily satisfied and have no ambition to labor for maximum yields.

Probably the one most serious problem faced by agriculture is the continuous loss of many of its brightest boys and girls to the city. Over the centuries, such losses may have disastrous effects. It is for this reason that so much attention has been paid within recent years to making farm life more attractive. But the fact remains that the operation of a successful farm calls for a great deal more skill than is required to attain a similar standard of living in industry.

A great deal of effort is now being put into agricultural conservation, both of our farming land and the people who live on it. When the TVA undertook its enormous program that was designed to combine the improvement of navigation, the control of floods, and the raising of the economic and social level of the peoples of the surrounding area, scarcely anyone believed it could attain its ends. But it is fighting its way through. Out of this very complicated experiment may grow a pattern that can be applied to great advantage to other large areas of land in this country. If not, we shall have to design another system, for we cannot stand idly by and allow nature to take its course in those areas where economic conditions have fallen to such a low level that poverty, disease, and ignorance take control.

It must be remembered that agriculture is important to the nation not only because it produces the necessities of life but because farmers represent a great stabilizing influence on the thinking of the nation, and their sons and daughters are needed for the rejuvenation of the city. Except for the constant influx of farm youth, one wonders what would become of the city. Farm families constitute about one-fourth of the nation's population, but they supply about one-third of its youth. It is imperative, therefore, that all of us stop to consider from time to time whether or not all is well on the farm. What those of us who are directly concerned with this problem are striving for is greater efficiency, more permanency, less drudgery, and higher standards of living.

It is conceivable, of course, that present agricultural procedures may, in due time, become as obsolete as has the forked-stick method of our far-distant forefathers for plowing the soil. There is no longer any question about our ability to grow plants without the use of the soil—and on a large scale. It is possible that the solution-culture method of growing plants, using sand or gravel for standing room, may undergo considerable expansion after the war is over. But scientists are not content with that accomplishment. Careful search

is now being made for the secret of the chlorophyll of green plants through which the sun's energy is translated into carbon compounds. There is reason to believe that, by microbiological and chemical procedures, we shall ultimately be able to synthesize every one of the organic compounds conntained in plants and required by animals. Only the essential mineral elements would then have to be added to these synthetic products to yield complete foods. Such foods could be artificially flavored and colored, and they could even be molded into appropriate shapes to satisfy our aesthetic senses.

But with a world war raging it seems safer to depend upon the soil, and the crops that grow on it. And if we are to place our primary dependence there for many centuries to come, as we very probably shall have to do, it would be well to recognize that the "good earth" must be kept good both during and long after the war, and that the well-being of those who cultivate the land as well as of the land itself is a matter of concern to all of us. For the farmer is the modern Atlas on the strength of whose shoulders the security of the world, in surprisingly large part, depends.

GREAT TEACHERS OF SCIENCE: II. LOUIS AGASSIZ

JAMES D. TELLER
The Adjutant General's Office, War Department

JEAN LOUIS RODOLPHE AGASSIZ was one of the great science teachers of all time. The secret of his greatness as a teacher is to be sought not only in his own intense love of pure knowledge, but also in his ever increasing desire to apply that knowledge in the guidance of the lives of other people. As a scientist he was a master because he himself had learned to use a sword for stripping the veil of ignorance from many natural phenomena; as a teacher he was a genius because he early learned how to instruct others in the use of this sword. While Agassiz engaged in little formal study of the psychology of learning, his practices show a keen understanding of its fundamental principles. From a study of the relative emphasis which he placed upon the laboratory, the lecture, and the textbook as aids in the learning process, we in the twentieth century can profit greatly.

AGASSIZ'S USE OF THE LABORATORY

Agassiz carefully discriminated between his special students and his general students, between those who were training to become naturalists and those who wished such a knowledge of nature as would make the world at least partially intelligible to them. We shall consider his use of the laboratory in the training of naturalists first.

Agassiz believed that a year or two of natural history, studied as he understood it, would give the best training for any kind of mental work.[8] The training he emphasized consisted of two essentials; first, instruction in accurate observation, and second, guidance in the making of fertile comparisons. Thus, he tells us:

> The education of a naturalist, now, consists chiefly in learning how to compare. If he have any power of generalization when he has collected his facts, this habit of mental comparison will lead him to principles, to the great laws of combination.[3]

He further warns that this method of observation and comparison is no Aladdin's lamp but involves sweat and tears. One must not expect too much. The results of a whole lifetime are very small. He cites his own life as an illustration:

I have devoted my whole life to the study of nature, and yet a single sentence may express all that I have done. I have shown that there is a correspondence between the succession of fishes in geological times and the different stages of their growth in the egg,—that is all. It chanced to be a result that was found to apply to other groups and has led to other conclusions of a like nature. But, such as it is, it has been reached by this system of comparison, which, though I speak of it now in its application to the study of natural history is equally important in every other branch of knowledge. By the same process the most mature results of scientific research in Philosophy, in Ethnology, and in Physical Science are reached.[3]

Agassiz further states as a general principle governing his practices in the training of naturalists that the comparison should be limited to a thorough study of a few representative species in all their relations to one another instead of a superficial acquaintance with a large number of species. In support of this principle he cites the powerful influence of De Candolle upon the progress of botany even though in his teaching he was able to illustrate the fundamental principles of his science with the aid of a dozen plants judiciously selected. Thus, he concludes:

. . . The study of Species as the basis of a scientific education is a great mistake. It leads us to overrate the value of Species, and to believe that they exist in Nature in some different sense from other groups; as if there were something more real and tangible in Species than in Genera, Families, Orders, or Branches. The truth is, that to study a vast number of Species without tracing the principles that combine them under more comprehensive groups is only to burden the mind with disconnected facts, and more may be learned by a faithful and careful comparison of a few Species than by a more cursory examination of a greater number.[3]

In applying these principles in the laboratory Agassiz used a true inductive approach. To Agassiz the laboratory was not a place (as it has become in our schools today) for the verification of generalizations suggested by the teacher to the student. It was a place where the student would observe and compare and generalize for himself. Agassiz was a firm believer in the pedagogical principle of activity: we learn to observe by observing; we learn to compare by comparing, and we learn to generalize by generalizing. Merely observing the objects to which our eyes are directed, merely comparing facts which we have been instructed to compare, merely verifying the generalizations which the teacher has explained—are not instances of true observation, comparison, and generalization in the sense in which Agassiz uses these terms. Instead the student must start with the raw materials of nature, perhaps some mixed fish bones, some assorted trilobites, or some miscellaneous shells; he must observe without help from the teacher; he must discover similarities and differences; and he must generalize his findings.

Such a method places the teacher in a difficult position, and one to which most teachers are not accustomed, a position which demands the teacher's silence. Listen to Agassiz tell of his dilemma to his assembled students at Penikese Island, Massachusetts:

I do not wish to communicate knowledge to you, you can gather that from a hundred sources, but to awaken in you a faculty which is probably more dormant than the simple power of acquisition. Unless that faculty is stimulated, any information I might have about natural history would soon fade and be gone. I am therefore placed in a somewhat difficult and abnormal position for a teacher. I must teach and yet not give information. I must, in short, to all intents and purposes be ignorant before you.[14]

The method also places the student in a difficult position and one to which most students are not accustomed, a position which places the student on his own initiative. After the son of Henry J. Bigelow, the eminent surgeon of the Harvard Medical School, had spent a week in Agassiz's laboratory and described how he had spent his time in looking at a trilobite, the following laconic conversation ensued between father and son:

"What, no book!"—"None."—"No instruction?"—"None."—"Nothing else said?"—"Nothing."—"Nothing to guide you, no sketch

or anything?" — "Nothing." — "Well, that is exactly the way a puppy has to learn how to live and get his living." [5]

But, as Charles W. Eliot reminds us, what a puppy learns, he learns very well. And Agassiz believed that it is only in imitating the puppy's method of learning that young people will learn to observe, compare, and generalize. He was firmly convinced that a teacher's first responsibility was to give the student an opportunity to do some observing, comparing, and generalizing for himself.

For a description of this method we may go to the published accounts of some of Agassiz's students. We shall relate the experiences of Nathaniel Shaler in Agassiz's laboratory in some detail and supplement them as seems desirable.

It was in the autumn of 1859 that Shaler first made Agassiz's acquaintance. Shaler was then eighteen years of age. During the summer he had deserted the humanities after his tutor, who was preparing him to enter the sophomore class at Harvard, had advised him to memorize a long list of rules for scanning Latin verse although Shaler could scan without having memorized the rules. Upon reading Agassiz's "Essay on Classification" and finding in it "something at once of science and philosophy," he decided to enter the Lawrence Scientific School. Agassiz was then fifty-two years old and his genial and engaging face as well as his manner captivated Shaler. [19]

At this time each professor determined the fitness of students to enter his classes. Agassiz gave Shaler an oral examination. He explored his acquaintance with Latin and Greek, but was not at all concerned about the rules for scanning verse; they talked together in German and read some French; they discussed the "Essay on Classification" and Schelling's influence on philosophy; and upon hearing that Shaler had had some training in fencing, Agassiz required him to bring his foils and mask for a bout. However, as Shaler relates, the professor did not fare well in this test, for,

> . . . Though not untrained, he evidently knew more of the Schläger than of the rapier. He was heavy-handed and lacked finesse. [19]

That part of the examination concluded, Shaler hoped that he would now be allowed to tell what he knew about animals, plants, fossils, and rocks. Instead he was put through the ordeal which one observer has aptly described as the "kill-or-cure plan." Shaler was assigned a small pine table in Agassiz's primitive laboratory and museum. A rusty tin pan and a small fish were placed in front of him. He was instructed to study the fish without reading or without talking to any one. To the usual student query, "What shall I do?", Agassiz replied in effect, "Find out what you can without damaging the specimen; when I think you have done the work I will question you." [19]

Shaler was ready to be questioned on the fish within an hour. However, Agassiz did not return to his table that day, nor the second, nor the third. Observing that Agassiz was watching him, Shaler sensed a game. Accordingly, he made a serious study of the fish. He noted the shape and arrangement of the scales, the form and placement of the teeth, and many of its other features. After spending about a hundred hours in this way, he thought he had compassed the fish. On the seventh day Agassiz returned and inquired, "Well?" Shaler disgorged his learning for an hour while Agassiz puffed away on his cigar. Finally, Agassiz walked away saying, "That is not right." [19]

Shaler was now convinced that Agassiz was trying to find out if he were capable of doing hard, continuous work without the support of a teacher. He decided to meet the challenge. So he went at his study of the fish anew, even discarding his first notes. At the end of another week of ten hours a day labor, he had secured results which astonished himself and satisfied his inquisitor. Without a trace of

praise in words or manner, Agassiz signified that his study of the fish would do by placing in front of Shaler about a half a peck of bones, telling him to see what he could make of them.

Shaler soon found that the bones were the skeletons of half a dozen fishes of different species. He decided that the problem was to fit the separate bones together in their proper order. This task required two months or more. In this period he received no help from Agassiz other than an occasional look accompanied by the stereotyped remark: "That is not right." Finally the task was completed, and he was set upon alcoholic specimens representing about twenty species of *Pleuronectidae,* or side-swimmers.

In the same years that Shaler enrolled to study geology with Agassiz, Samuel H. Scudder entered the scientific school to study entomology. He was put through a novitiate similar to that of Shaler. However, in his case, Agassiz seems to have been more communicative and openly appreciative. Scudder was directed to study a specimen of *Haemulon,* a genus of tropical fishes known as "grunts." After he had spent several hours looking at the fish, he decided to draw it. This action elicited from Agassiz the comment:

> That is right; a pencil is one of the best eyes. I am glad to notice, too, that you keep your specimen wet and your bottle corked. Well, what is it like? [17]

Upon hearing Scudder's rehearsal of parts whose names were still unknown, Agassiz remarked:

> You have not looked very carefully. Why, you haven't even seen one of the most conspicuous features of the animal, which is as plainly before your eyes as the fish itself. Look again! Look again! [17]

Next morning, after Scudder had succeeded in discerning the feature desired, the symmetrical sides with paired organs, he thought he was ready to leave the fish and eagerly inquired, "What next?" To this query came the rejoinder, "Oh, look at your fish!" So for three more days Scudder looked, and looked, and looked. Scudder's evaluation of this lesson in looking is as follows:

> This was the best entomological lesson I ever had,—a lesson whose influence has extended to the details of every subsequent study; a legacy that the professor has left to me, as he left it to many others, of inestimable value, which we could not buy, with which we cannot part.[17]

Both Shaler and Scudder in the beginning worked only with their two eyes and two hands to help them. However, another student, Henry Blake, was permitted to use dissecting instruments and the microscope in his novitiate with his alcoholic specimens of the genus *Gambusia.* [4]

David Starr Jordan tells us that Agassiz turned men from their chosen groups and gave them for inductive study something of which they knew nothing. [10] He believes that his reason was to throw the student entirely on his own resources without confusing recollections or bad habits. In support of his generalization, Jordan cites the work of Shaler, a geologist, on a series of "flounders"; of Scudder, a student of butterflies, on the "grunts"; and of Edward S. Morse, an artist, on the common clam. However, Addison Emery Verrill says that Agassiz treated each one of his students differently according to the amount of knowledge and experience the student had previously acquired, and "often in line with what the student had done before." [21] In his own novitiate Verrill was given a badly mutilated old loon and told to prepare the skeleton. Since he had mounted birds for several years before coming to Agassiz, he did an excellent job, causing Agassiz to express regret that he had not given him a better bird with unbroken bones. His next assignment was a blue heron, and before the end of his first year he was given entire charge of the birds and mammals in the museum.

These descriptions of Agassiz's "kill-or-cure plan" in operation could be multiplied manyfold. Thus, Burt G. Wilder spent the

ordeal with "a dozen young acanths," or dog-fish sharks, [22] while Alpheus Hyatt was given a lot of mixed fish skeletons, more or less broken, to "see what he could make of them." [21] Evidently Agassiz's treatment of students intending to become naturalists was highly individualistic. As William James, another of his students, tells us, he did not even wait for students to come to him, but would make inquiry for promising youthful collectors and then write urging them to come and study with him. [8] On their arrival, he simply encouraged them to see for themselves, and determined their qualifications to become naturalists. Of course we must not assume that they all succeeded. Blake tells the story of one student who, on being given a badly decomposed alcoholic fish to skeletonize, gazed for a short time at the specimen, left the laboratory, and never returned. [4] Those who survived this introductory ordeal, however, recognized it, as Scudder did, as one of the most valuable legacies that could have been left them by their master. The ordeal itself as an element in Agassiz's method helped to spread his fame as a teacher. As James remarked after the death of Agassiz:

> There is probably no public school teacher now in New England who will not tell you how Agassiz used to lock a student up in a room full of turtle shells, or lobster shells, or oyster shells, without a book or word to help him, and not let him out till he had discovered all the truths which the objects contained. [8]

Although Agassiz threw his students on their own resources at first, after they had completed their novitiate, he immediately put all his intellectual capital at their disposal. They had access to his most precious specimens, his unpublished investigations, and his ideas on the problems in natural history which were in need of study. With his guidance each student chose the group in which he wished to carry on original research. Thus, Shaler studied the brachiopods as the best group of fossils to serve as data in determining the Paleozoic horizons. [19] As Agassiz and his students explored fields together, he awakened in them an enthusiasm for constructive work. Scudder relates that his work on butterflies originated in a plan of Agassiz's students "to describe within the compass of a series of volumes all the animals of New England, with special reference to their life histories." [18] Again, A. S. Packard, Jr., in his *Guide to the Study of Insects,* acknowledges his "indebtedness to Professor L. Agassiz for many of the general ideas, acquired while the author was a student in the Museum of Comparative Zoology at Cambridge, regarding the arrangement of the orders and classes, and the morphology of the articulates." [15]

Moreover, Agassiz sought to develop each of his students into something more than a mere species-describer. He wished to develop men who could deal with their subjects in different ways. Consequently, he required not only a monograph in the student's specialty but also a scientific lecture, a popular lecture, and a simple child's tale. [19] Shaler paraphrases his advice to him on writing as follows:

> In amplifying the idea he said it was well to be able to give in a single sentence the whole matter of months of labor, in a form so true that a scientific man could read in it, not only the extent of your knowledge, but also the habit of your mind. He declared he could learn all this from an answer couched in the most laconic form. [19]

Out of the intellectual goodfellowship thus developed in the laboratory grew the warmest relations between Agassiz and his students. He tried to help his students to improve by offering constructive criticism at every opportunity. William James in a letter to his father evaluates his method of giving criticism thus:

> . . . He has a great personal tact too, and I see that in all his talks with me he is pitching into my loose and superficial way of thinking. . . . Now that I am become more intimate with him, and can talk more freely with him, I delight to be with him. I saw only his defects at first, but now his wonderful qualities throw them quite in the background. I am convinced that he is the man to do me good. [7]

James, referring to himself as X, relates how in one of his conceited moments Agassiz cured him with the following "salutary cold-water therapeutic":

> Mr. X, some people perhaps now consider you a bright young man, but when you are fifty years old, if they ever speak of you then, what they will say will be this: "That X—oh yes, I know him, he used to be a very bright young man." [8]

On another occasion James heard Agassiz say to a student who had propounded some glittering theoretic generality: "Mr. Blank, you are *totally* uneducated." [8]

Wilder, too, testifies as to Agassiz's method of giving criticism. After helping Wilder to get an appointment at Cornell, Agassiz arranged for him to deliver a course of six "University lectures" at the Museum in Cambridge in order to give him practice in speaking. He warned him to prepare carefully because he intended to give him "a raking down." Agassiz attended all of the lectures and discussed Wilder's methods very frankly with him. During Wilder's first year at Ithaca Agassiz attended several of his lectures on physiology. In one lecture dealing with the structure and functions of the heart, Wilder used several excellent charts and models but no actual specimens. After the lecture —but let Wilder tell his own story:

> I believed that I had done very well, and accompanied him down the hill toward his hotel in the hope that he would say something complimentary. All he said was, "After lecturing upon a subject I have found it a good plan to go to work and study it some more." Then he began to talk of the glacial scratches upon a big rock that we passed. The justice of his criticism was equal to the delicacy of its conveyance. [23]

In his relations with students Agassiz was not given to joking, although he sometimes exhibited a keen sense of humor. On one occasion Shaler discovered that in accordance with Agassiz's scheme of classification one of his species of side-swimmers had cycloid scales on one side and ctenoid scales on the other. With a malicious pleasure he took the nondescript to Agassiz for classification. Whereupon Agassiz said: "My boy, there are now two of us who know that." Blake relates how on another occasion the students, in an effort to catch the professor, colored a bug and substituted the legs and antennae of another insect, and then requested Agassiz to name it. He nonchalantly replied, "Well, gentlemen, I think it is a humbug." [4] However, he would not tolerate student pranks which tended to interfere with the main business of a school, learning. He dealt with such instances with the maximum severity. During the first night at Penikese six young men, in order to express their disapproval of Agassiz's policy of coeducation, threw into the women's quarters a huge doll baby fashioned from pillows and blankets. The next morning at breakfast Agassiz calmly informed the assembled students that a steamer was waiting for the six young men who had perpetrated the prank. Student appeals in behalf of the culprits were of no avail. The sentence was executed. [11]

It is instructive to differentiate carefully between Agassiz's use of the laboratory and Huxley's system. Whereas Agassiz, as we have emphasized, employed a true inductive approach with his special students in the laboratory, Huxley used the laboratory to enable his students to verify that which they had heard in his lectures or read in his textbooks. The Huxleyan system is the one upon which nearly all biological teaching today is modeled, [16] the Agassizan system is the one that needs to be improved and extended if we would teach the essentials of scientific method with which Agassiz was concerned; the Huxleyan system is a method of teaching laboratory verification, the Agassizan system is a method of teaching laboratory discovery; the Huxleyan system uses a deductive approach, the Agassizan system uses an inductive approach.

At Penikese Agassiz experimented with the idea of adapting to groups the individual inductive laboratory method by which he had trained a generation of zoologists. In this experiment—his first

and, unhappily, his last—he wavered between Huxley's system and his own. But in so far as he followed Huxley he did violence to his whole conception of the way in which scientific method should be taught. Perhaps if he had lived to undertake a second experiment he would have created a popular system which would have done for the teaching of the process of making scientific generalizations that which Huxley did for the teaching of the process of verifying scientific principles. The two processes are not the same; the challenge to develop a practical classroom method of teaching the former remains.

In his instruction of general students Agassiz made little, if any, use of the laboratory. When he did advise or use what might be termed laboratory experiences for these students, it was the Huxleyan type of laboratory experience, a process in which the student is taught to verify zoological principles which have been explicitly stated by the book or teacher. It is this process which he advises for the readers of his *Contributions:*

> I believe, that, in America, where Turtles are everywhere common and greatly diversified, a student could not make a better beginning than by a careful perusal of this part of my work [the part dealing with Turtles], specimens in hand, with constant reference to the second chapter of the First Part [the part explaining the general principles of classification]. [2]

Such advice is in direct opposition with the principles governing his treatment of special students, as we have seen. What Agassiz did on the field trips which he took with his geology students is also more closely akin to the system perfected by Huxley than to that which Agassiz used with his special students. Theodore Lyman has left the following description of the procedure:

> . . . It was pleasant to see him, at the head of a score of us youngsters, making his way towards the pudding-stone quarries in Roxbury. His face wore an easy smile, and, as his quick, brown eye wandered over the landscape, it saw more than did all our eyes put together; for he looked, but we only stared. Near by, like a sort of lieutenant, walked Jacques Burkhardt, the life-long friend and artist of the great professor. Though his beard was white, he never grew old; and, to the last, preferred the company of collegians. Whenever we came to a gravel pit or a railway cut, the professor would stop, and would expatiate on the structure of the drift with as much interest as if he saw it for the first time. This enthusiasm, fresh and untiring over trite facts, was a source of immense power to him. . . . Of the section of conglomerate in Roxbury he was never tired of talking; and, over and over again, to different sets of hearers, he would explain the cleavage planes of the rock; and how the cleavage had cut right through hard pebbles, like a knife; then the structure of the stone itself, and the different origins of flat and rounded pebbles; and finally he would climb to the top of the ledge, and earnestly show the grooves and scratches running north and south, and the surface polished by glaciers. [13]

Agassiz had been using this method when Huxley was only a boy, but he never systematized it as did Huxley. Mrs. Agassiz gives the following description of his early use of the method with children:

> One can easily imagine what joy it must have been for a party of little playmates, boys and girls, to be taken out for long walks in the country over the hills about Neuchâtel, and especially to Chaumont, the mountain which rises behind it, and thus to have their lessons, for which the facts and scenes about them furnished subject and illustration, combined with pleasant rambles. From some high ground affording a wide panoramic view Agassiz would explain to them the formation of lakes, islands, rivers, springs, water-sheds, hills, and valleys. . . . When it was impossible to give the lessons out of doors, the children were gathered around a large table, where each one had before him or her the specimens of the day, sometimes stones or fossils, sometimes flowers, fruits, or dried plants. To each child in succession was explained separately what had first been told to all collectively. . . . The children took their own share in the instruction, and were themselves made to point out and describe that which had just been explained to them. They took home their collections, and as a preparation for the next lesson were often called upon to classify and describe some unusual specimen by their own unaided efforts. [1]

AGASSIZ AS A LECTURER

One of Agassiz's favorite educational dogmas was that all biological instruction should be objective. Yet Wilder tells us

that, during the five years of his attendance upon Agassiz's lectures, they were seldom illustrated otherwise than by his ready and graphic blackboard drawings. [22] Wilder attributes this lack of demonstration in Agassiz's lectures to the fact that the time between lectures was so crowded that he could not determine upon the precise subject long enough in advance of the lecture to bring together the necessary specimens or charts.

Shaler felt that Agassiz's lectures were not profitable to his students except for his contagious enthusiasm in approaching his subject and for his description of the masters he had known. He believed that the lectures covered too limited a field to give the student much knowledge of general zoology or geology. [19]

Lyman, also, called attention to Agassiz's enthusiasm for his subject:

> No village school-master was ever more patient than he in teaching elementary zoology; and when, for the thousandth time, he would write with chalk on the blackboard the words Vertebrata, Articulata, Mollusca, and Radiata, it was with a zeal and vigor that showed he was doing something agreeable. [13]

Not only did Agassiz succeed in escaping the monotony which some teachers experience in lecturing on the same subjects year after year, but he once confessed to Longfellow that in beginning a course of lectures he even experienced *"une peur terrible."* [12]

Agassiz's skill in chalking as he talked added greatly to the effectiveness of his lectures. Thus, Lyman remarks that, " If he were saying, ' The salmons have a peculiar fatty fin, called the adipose,' almost with the words would appear an unmistakable chalk outline of the fish." [13] Mrs. Agassiz tells us that in discussing the metamorphosis of an insect, he would draw the insect on the blackboard in the successive stages of its development as he talked until suddenly the winged creature would appear as if it had burst from its chrysalis. [1]

Another feature of Agassiz's lectures, as Shaler suggested, was his vivid pictures of the masters under whom he had studied. He had a high appreciation of the place of biography and history in awakening the interest of his students. Moreover, he used the history of his science to aid the student in understanding the elements of research in his field. He believed that " some idea of the progress of Natural History, of its growth as a science, of the gradual evolving of general principles out of a chaotic mass of facts, is a better aid to the student than direct instruction upon special modes of investigation." [3]

Blake tells us that after a lecture the students would gather about the desk to ask questions. On one of these occasions a student picked up a valuable fossil shark's spine and accidentally let it fall. It broke into three pieces. No one dared to speak until finally Agassiz said, " One of the first things to learn in studying natural history is how to handle specimens." [4]

Just as the laboratory was the chief agency which Agassiz used in the training of naturalists, so his lectures were almost the sole means of instruction which he employed with his general students and his vast popular audiences. Yet in a sense he brought the spirit of the laboratory into the lecture room. As James expressed it,

> No one sees farther into a generalization than his own knowledge of details extends, and you have a greater feeling of weight and solidity about the movement of Agassiz's mind owing to the continual presence of this great background of special facts, than about the mind of any other man I know. [7]

AGASSIZ'S USE OF BOOKS

Agassiz was the apostle of the great book of nature. He unceasingly admonished his students to " read Nature not books," explaining to them that, " If you study Nature in books, when you go out-of-doors you cannot find her." [14] Such an attitude toward books is consistent with his emphasis on an inductive approach to the study of nature. However, his posi-

tion was not, as has sometimes been assumed, [13] one of antagonism to the use of all textbooks in the learning process. Rather it was against what he considered their improper and even vicious use that his criticism was directed. Rote memorization from textbooks, good or bad, exasperated him.

Jordan says that Agassiz once declined an invitation to write a textbook in zoology for the use of schools and colleges and advised the publishers that "the less of that sort of thing which is done the better." [9] In talking to his students at Penikese—for the most part teachers of natural history—Agassiz expresses the hope that he will "live long enough to make textbooks useless and hateful." [14] In the face of evidence that Agassiz's opposition was not to textbooks but to their improper use, it would seem that such statements are literary exaggerations to impress upon his students the necessity of beginning the study of nature with nature herself. If these statements are explained by assuming a wholesale opposition to all textbooks on Agassiz's part, then Agassiz's practice is inconsistent with his theory. While Agassiz is no model for consistency —he himself advised his students to "dare to be inconsistent" [14]—nevertheless the evidence seems to show consistency on his part at this point. In his less rhetorical moments, at times when he expanded upon his slogans, he expressly stated that his opposition was not to all books but only to worthless ones. [14] Then, too, in collaboration with A. A. Gould he himself wrote a textbook of zoology which had great influence. In the third place, he made definite suggestions for the improvement of textbooks. He believed that only productive scholars with a wide knowledge of the original research in the field should attempt to write textbooks. Further he advised that textbooks should be made in the country where they are to be used and should be illustrated with the objects common to that country. These illustrations should be "telling" in as many directions as is possible. [14] Fourthly, Agassiz's own students used textbooks at certain stages of their development. Thus, Shaler, with Cuvier's *Le Regne Animal* as a guide, "made a tolerably near acquaintance" with perhaps two hundred species. [20] Of this book, Agassiz said:

> It is a library in itself. It is the best work of its kind in any language, and ought to be in every school library. It is the fountain from which are drawn all the illustrations of modern text-books. [14]

Huxley's *Comparative Anatomy* he thought to be the "best work on that subject extant." He judged Darwin's *Animals and Plants under Domestication* to be "the best and fullest presentation of the facts," while his monograph on Cirripedia he thought to be "a model of full and accurate investigation." [14] Finally, Agassiz gave his students at Penikese directions for selecting books for study. While in general he advised the use of monographs prepared by men who had made the investigation of a single branch the work of a lifetime, he also recommended a list of fourteen books, including six of which he was the author or co-author.

Agassiz not only directed his criticism against the misuse of good books, but he also conducted a crusade against worthless books and their publishers. Thus, he tells his students at Penikese:

> There are great business concerns engaged in the manufacture and sale of these worthless books who are our greatest enemies. They are really circulating educational poison, and I beg of you don't shrink from rebuking them at every opportunity. I have aroused very serious opposition to my work by stating these things openly, but I shall continue to do it as long as my strength lasts. [14]

In conclusion, while Agassiz regarded books as tools of a secondary value to those who are really endowed by nature with the power of making original researches, there is a definite place for books in his method of teaching natural history. However, he never integrated the laboratory, lecture,

and book into a comprehensive system of biological instruction, as did Huxley.

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A HUNDRED YEARS AGO IN SCIENCE EDUCATION AT THE JUNIOR-HIGH-SCHOOL LEVEL

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THERE was no junior high school a hundred years ago and thus no junior-high-school science, and in all probability the junior high school will pass from the American scene as a separate school and again there will be no junior-high-school science. But science teaching at the junior-high-school level a hundred years ago was an actuality, and the probabilities are that it will exist many hundred years hence.

The discussion which follows is a survey of the status of science education at the junior-high-school level during the three decades from 1827 to 1857. It was in 1827 that both Massachusetts and Vermont provided by law for the instruction of children in geography, which at that date included science material. It was in 1857 that the National Teachers Association (the forerunner of the National Education Association) was organized, with explicit recognition of the need for study and revision of the educational program.

During the period from 1827 to 1857, much science material was introduced into schools. Lyceums were organized which attempted to develop an interest in collecting local science specimens for exchange

between school children of different counties and states, and aimed to aid schools in obtaining scientific appliances. William Russell's *American Journal of Education* (1826–1831) and other periodicals published articles and material on science, some of which were prepared and intended for use by teachers in the schools.

CONTEMPORARY CRITICISM AND COMMENT

In 1829 the *American Journal of Education* observed that:

> The whole circle of the sciences is examined and relished, to some extent, by children; . . . The experiments tried by them, in chemistry, mechanics, hydrostatics, pneumatics, optics, botany, mineralogy, &c., are innumerable, and all calculated to give them knowledge which they most need, and which they constantly use in their daily pursuits in life. [1]

But many persons were questioning whether a child should be taught science subject matter before being capable of fully comprehending it. Some believed that teachers were devoting time to science instruction which might better be used for other subjects or for instructing children studying at lower levels.

Many persons complained because of the want of good science textbooks and because too many children were studying from textbooks instead of studying nature. Others were criticizing the existing school programs because of the meagerness of the science offerings. Samuel Hall wanted more instruction in the elements of chemistry and natural philosophy, and Asa Gray more in the natural sciences. Henry Guyot advocated instruction in physical geography. Horace Mann and William Alcott desired school instruction in physiology.

It was said that science instruction should emphasize the first-hand examination of natural phenomena, and it was proposed that geography instruction begin with the home environment. Methods which failed to make use of objects in illustrating and communicating ideas were criticized. When natural objects were not obtainable, it was suggested that charts, models, apparatus, and other visual aids be used. Even when natural objects were available, other visible illustrations were to serve as supplementary aids. More extensive use of the blackboard was recommended.

Objections were directed toward methods requiring the committing of words to memory rather than the development of ideas. Teaching by oral lessons was proposed by many educators of the period. The question and answer method was to be used where questions were not *leading* questions and answers were given in the language of the student. Teachers were to prepare their lessons thoroughly.

THE SCIENCE SUBJECTS OFFERED

Geography was being taught in almost all schools. Several states followed the lead of Massachusetts and Vermont and required that geography be taught in their common schools. Natural philosophy, astronomy, botany, chemistry, physiology, geology, and a few other sciences were being introduced into the common schools at the junior-high-school level, the extent of their adoption being in about the order here mentioned. Natural history was comparatively neglected.

There were relatively few high schools during the period. Many of those that did exist offered geography, astronomy, and natural philosophy in varying combinations and amounts to first-year students. At this level sometimes botany, natural history, natural theology, hygiene, anatomy, physiology, mineralogy, geology, and zoology were offered. By 1857, physiology, natural philosophy, and either common school geography or physical geography were usually the first-year high-school science subjects.

The quasi-private schools welcomed youths of junior-high-school age who could pay the tuition fees. A common entrance age, particularly for female seminaries, was twelve years, and a complete program ordinarily was planned to cover three years'

work. A popular policy of the quasi-private institution was to teach what parents and pupils wanted taught, and usually at the level wanted. Geography, natural philosophy, astronomy, chemistry, and botany were the sciences customarily taught at the junior-high-school level in the academies of the period.

In all schools at the junior-high-school level, geography and natural philosophy were the most frequently offered courses providing for instruction in the elements of science. Anatomy, chemistry, botany, and physiology often were offered after about 1840. Natural history, mineralogy, geology, and a few of the other sciences were rarely studied. Hygiene, electricity, hydrostatics, pneumatics, meteorology, optics, and magnetism were subjects that disappeared from the programs of studies —for the time being, for some have reappeared—but they were, in varying degrees, adopted as parts of other science subjects which continued to be offered.

SCIENCE TEXTBOOKS

Textbooks in common school geography, during the period 1827–1857, continued to present much science subject matter. However, the amount of astronomical material to be found in these geographies decreased. Early in the period, the authors introduced the discussion of the relation of plant and animal life in the environment. By 1844, physical geography material was being emphasized in some geography textbooks. Authors disagreed as to whether the physical geography subject matter should be treated separately or in connection with geography material.

Physical geography textbooks (which treated natural phenomena only) were introduced in 1855. The early writers organized the subject matter into three parts, treating the three "spheres"—atmosphere, hydrosphere, and lithosphere —with sometimes an added part on plants and animals, or perhaps on the physical geography of the United States.

Some differences of opinion existed among writers of the early natural philosophy and chemistry textbooks as to what subject matter should be included. Astronomy was considered a part of natural philosophy early in the period but was soon recognized as a separate subject. The early textbooks of both natural philosophy and chemistry treated the various forms of energy, called the "imponderable agents." (The authors of one series of science textbooks as late as 1867 placed all their subject matter on electricity in their chemistry textbook.)

The method of using "conversations" to present subject matter in natural philosophy and chemistry textbooks came into disfavor. The method of presentation became one of description, illustration, and demonstration experimentation.

The early astronomy textbooks contained subject matter on the earth, the solar system, and the sidereal system. Later textbooks added material on practical astronomy. The material of early astronomy textbooks referred to charts and celestial globes for observation work, but in 1845 Burritt's widely used *Geography of the Heavens* called for the first-hand study of the stars, planets and constellations.

The early botany textbooks were designed to aid students in recognizing and classifying plants. It was customary to begin the textbook with a discussion of a scientific arrangement of plants. New textbooks appeared, still emphasizing classification, but first giving a description of the several parts of plants. In 1857 Gray published his first textbook on botany, retaining the idea of classification and also placing emphasis upon the structure, organs, growth, and reproduction of plants. He discussed the importance of plants in the scheme of creation.

Natural history and zoology were usually synonymous terms so far as science textbooks were concerned. The subject matter found in natural history textbooks

was limited to a treatment of animals, their respiration, motions, instincts, senses, and so forth.

The early human physiology textbooks described the functions of the principal organs of the body. By 1846, subject matter concerned with anatomy and hygiene, as well as physiology, appeared in the textbooks. The different organs of the human body were first described according to structure, then as to function; and finally the conditions on which health and disease were believed to depend were described. The subject matter which received the most attention was that of anatomy. The method of treatment was wholly descriptive.

A few years before 1857, there appeared books consisting of questions and answers, treating the common phenomena of life, and drawing materials from all science fields. Some of these books contained sections describing experiments to be performed. One which was used rather extensively in the schools at the junior-high-school level was Peterson's *Familiar Science*—sixty-seven thousand copies were issued by 1856, eighty-seven thousand copies by 1858.

OBJECTIVES AND METHODS

The objectives which were emphasized throughout the period were informational and religious—a knowledge of things, of the laws of nature, and of the wisdom, power, and greatness of the Creator. The mental disciplinary objective received some attention. Before the middle of the century the proposed objectives began to emphasize the development of habits of observation, discrimination, and imagination.

During the early part of the period 1827–1857, textbook teaching, with memorization, was predominant, but the inductive method of instruction was gaining in favor. In academies and high schools, lectures illustrated by means of science apparatus, models, mineral collections, animal and plant specimens, engraved drawings, and demonstration experiments were very popular. The illustrated lecture method soon found its way into grammar grades on a less extensive scale.

By about 1845, oral instruction and the use of the blackboard came into favor. Much diagramming was used as a medium of "visible illustration" in teaching the parts of plants and animals, and even scientific principles. Also used for illustration were globes, orreries, tellurians, tide-dials, and mineral, animal, and plant collections.

Outside professional men were welcomed into the schools to give lectures on scientific subjects. Students rarely were permitted to perform experiments in natural philosophy or chemistry, but they could examine the mineral, plant, and animal collections; bring in specimens of their own; and make first-hand examination of the movements of the heavenly bodies. Field trips were made by some teachers and pupils to observe permanent collections, or to collect specimens of their own.

IDENTIFIABLE TRENDS

Throughout the period the trend was toward teaching more science material in the schools at the junior-high-school level than previously. Common school geography, physical geography, and physiology were gaining in favor as subjects to be offered at the junior-high-school level. The practice of offering the elements of natural philosophy, physiology, botany, meteorology, geology, and zoology as oral lessons to students at the grammar-school level was gaining in favor.

The informational and religious objectives were being supplanted by the mental disciplinary objectives, and memorization was being replaced by oral lessons, inductive teaching, the topical method, and the study of nature first-hand. There was a trend toward use of more "visible illustration." The blackboard, science equipment, models, and other means of supplementing

direct study of natural phenomena were coming into favor.

Much, of course, remained to be done, as educators of the day recognized. Addressing a teachers' convention at Philadelphia on August 27, 1857, William Russell stated that:

> The whole ground of education needs a thorough survey and revision, with a view to much more extensive changes and reforms than have been attempted. The cry for more healthful, more invigorating, more inspiring, more effective modes of culture, comes up from all classes of society, on behalf of the young who are its treasured hope. A truer and deeper investigation is everywhere needed in regard to the constitution, the capabilities, and the wants of man, equally in his temporal and his eternal relations. [2]

And much still remains to be done. It is still the task of educators to provide "more healthful, more invigorating, more inspiring, more effective" science education at the junior-high-school level.

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OREGON SURVEYS ITS TEACHING OF ELEMENTARY SCHOOL SCIENCE

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IN 1941 the State Board of Education of Oregon adopted a unified elementary school science program. A tentative guide was prepared to help teachers begin working in this program and to supplement the state-adopted science reader series.

The next year a committee began a research study to determine the progress made and to ascertain the problems teachers faced when working on an area which was new in part to many of them. Approximately fifteen hundred printed questionnaires were sent out, most of them through county school superintendents. Nearly five hundred forms were returned.

CHILDREN'S LIKES AND DISLIKES

Teachers reported on the units liked best by their children and on those liked least. Ninety per cent of the teachers named a unit liked best, but only 55 per cent gave data on a unit liked least. Table I summarizes these findings for the state as a whole.

Oregon is a rural state. Moreover, nature study and agriculture were formerly required. It is not surprising, then, that science units concerned with living things and with the earth and universe should be recorded as best liked in so many cases, and least liked in so few.

On the other hand, many physical science units, particularly those on force, energy, and gravity, were regarded by teachers as the ones least liked by their children. Among reasons indicated by teachers in explaining this are the lack of equipment and the uninteresting character of the subject matter. These reasons may be somewhat justified, but they may also be a rationalization for a more important reason. Physical science units are least liked by children, and, through inference, by their teachers, probably because they are the most book-taught units. A tabulation of methods of teaching showed that few experiments were performed in the direction of the physical science units under question. Probably poor physical science training causes teachers to rely on the science readers.

Health units were disliked much more than best liked. Teachers and pupils seem to have developed an immunity to health

TABLE I

NUMBER OF OREGON TEACHERS REPORTING LIKES AND DISLIKES OF THEIR PUPILS FOR EIGHTEEN SCIENCE UNITS, BY GRADES *

Unit Topics	*Grades*									
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*Total*
Seasons	0	2	1	0			1			10
	1	0	0	2			1			4
Weather	4	4	2	1	10	0		3	1	24
	3	5	1	3	4	1		2	0	19
Sun, moon, stars; the universe	4	3		21		11	4	32	4	79
	4	4		8		4	0	13	2	35
Earth's surface		0	3	1	8	4	7	19	1	43
		1	1	0	2	6	3	8	0	15
Introductory: scientific discoveries, etc.							1	0	0	1
							9	1	1	11
Animals	7	3	14	19	1	3	2		1	50
	0	0	4	2	0	2	0		0	8
Plants		0	1	0	1	1				3
		1	3	1	1	0				6
Ecology			1	1	5		1			8
			0	1	10		3			14
Protection			10							10
			1							1
Health				3		0	1	3	1	8
				8		5	1	5	3	22
Biology (living things)	1	7	1	8	11	16	7	4	4	59
	0	1	0	2	2	7	7	1	0	20
Agriculture, including conservation			1		0	3	1	6		11
			0		2	1	0	4		7
Work, machines		1	1	1	11		11	0	3	28
		1	1	2	1		2	1	3	11
Force, energy, gravity			2	2	1			9		14
			3	2	2			25		32
Heat					5	0	6	0		11
					4	3	6	3		16
Chemistry					3		24	1	0	28
					6		12	1	1	20
Sound						9				9
						7				7
Bird study					3	2				5
					0	0				0

* The numerator of the fraction indicates the number of teachers at that grade level reporting their students as liking the unit best. Conversely, the denominator indicates those who report the unit as liked least. Translated, the units on animals only for all grades are reported by 50 teachers as liked best by their pupils; 8 teachers report such units as least liked.

education as commonly offered, and science units on health are consequently stigmatized.

TEACHERS' PROBLEMS

Following the pattern of a discussion by Croxton [1], various problems were mentioned in the questionnaire. Teachers were asked to check the three problems that they met most frequently. Their collective rating of teaching problems in science is as follows:

1. Lack of equipment
2. Teacher lack of preparation in science
3. "No time for another subject"
4. Provision for individual differences in ability
5. "Too many children to perform experiments successfully"
6. Parents and school board regard experiments and field trips as a waste of time
7. Inadequate source materials on western flora and fauna
8. Difficulty of integrating science with other studies; repetition of subject matter of health and geography
9. "Can't get pupil interest"
10. Adopted textbooks unavailable

It should be noted that the chief problem in the eyes of the teachers was not that of lack of science preparation, although the members of the survey committee are inclined to regard this as the basic problem. The committee endorses the thoughtful remarks of Miss Florence Heffernan in discussing the status of elementary school science before the war:

> Children are eager for adventure in the field of science, but most of our teachers have not had the necessary science education to point the road to these adventures. The greatest problem in giving science its proper place in the elementary school curriculum lies in the limited training of teachers. [2]

An interesting sidelight on the teacher preparation problem is the reaction of teachers to a suggestion on the questionnaire that members of the committee visit their classrooms. Only 162 teachers said that they would be willing to have their science teaching observed. However, 270 were willing to have the committee meet alone with a dozen of their best pupils.

Teachers regard the acquisition of equipment as their major problem in science teaching. Seventy per cent of teachers reported this as a problem, almost double the number reporting the next ranking problem. As a reason for units which their classes liked least, teachers reported lack of equipment as most serious. In this connection, a number of teachers indicated that parents or school board looked upon science experimentation as a waste of time, making it hard to get funds for equipment.

Even discounting a certain amount of rationalization, it is interesting to discover that this teaching problem assumes such a large place in teachers' thinking. There should be concerted effort to make equipment for science experiences as easy to get as books and other supplies.

At the primary level especially, teachers indicated that the reading matter in the textbooks was too difficult. The publishers have apparently long sensed this and have now developed picture books to gear in with the reading readiness program. Although there is a trend to defer all reading in order to secure better child comprehension, the elementary science concepts do not necessarily have to be deferred. Indeed, easy experiments may help develop reading readiness, for they afford real experiences with things and ideas before the child reads about them.

Many rural teachers have indicated a need of helpful materials designed for rural schools. This is a general problem, and one to which the State Department of Education is giving considerable thought.

A number of teachers mentioned the need of biological science materials prepared for our state. They recognize the absence of such material, for most books are prepared in the East where many

plants and animals are different from those in Oregon and other western states. As an illustration, for study of native birds, colored pictures of the red-headed woodpecker grace Oregon schoolrooms, yet we are a thousand miles from the natural range of this bird. The Lewis woodpecker, distinctively western, is scarcely recognized. This is only one of scores of similar instances.

To many teachers, the state program in elementary science appears as just an added study in their already crowded curriculum. Lack of time to teach science is rated as third among their problems by teachers. A number of teachers mention that they integrate health and geography with science units. This is a sound psychological technique, and it saves time too.

In addition to checking statements of problems on the questionnaire, thoughtful teachers wrote concise statements of other problems in the teaching of science. For example, several teachers wondered how they could lead their students to think in science, rather than to tell them, in the traditional manner, what to think.

SUMMARY

Oregon teachers, by and large, agree on the necessity of incorporating science into the elementary school curriculum. For example, many are aware of the handicaps placed upon our fighting men through neglect to teach any organinzed program of science in the elementary grades. At the same time, for various reasons, Oregon teachers do not feel that they teach science now as effectively as it should be taught. Doubtless, teachers in many other states are going through the same experience in adapting themselves to a relatively new program.

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THE ABILITY OF SCIENCE STUDENTS TO MAKE CONCLUSIONS

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MUCH of the recent research in the teaching of science has dealt with those phases of science which are not directly concerned with factual outcomes. Such work has considered attitudes, appreciations, habits, and problem-solving abilities. Many of these endeavors have been concerned with a generally accepted aim of science education, namely, the ability of students to apply an experimental method of thinking. The acceptance of problem solving as a major aim of science education would then stipulate that, by definition, growth in the ability to make valid conclusions, as an integral part of the problem-solving method, is an important specific goal of science teaching.

RELATED EXPERIMENTAL STUDIES

Experimental studies which seek to test the efficiency of teaching methods in increasing skill in the ability to use the scientific method, and more particularly, the ability to infer, are unfortunately few in number. A careful perusal of the studies of Curtis [1], Nichols [2], Sinclair and Tolman [3], Bedell [4], Blair and Goodson [5], Eberhart and Hunter [6], Neuhof [7], and Howard [8], indicates that there is some evidence which disputes

the assumption that specific emphasis on scientific method and thinking in teaching procedures is essential or necessarily efficacious in the inculcation of these habits.

THE PROBLEM

Recently an experimental study has been completed which had as its purpose the determination of the efficacy of a problem-solving technique of teaching ninth-grade general science in terms of the students' ability to make conclusions. The investigation sought to answer the following specific questions:

(1) What is the effect of instructional emphasis on certain aspects of the ability to make conclusions in science, namely:
   (a) the ability of the student to state in his own words an inference (conclusion) from given facts?
   (b) the ability of the student to select the best conclusion from four proposed conclusions?
   (c) the ability of the student to evaluate proposed conclusions in terms of reasonableness, sufficiency, and pertinency of data?

(2) What is the relationship between mental age of the student and:
   (a) each of the three abilities indicated?
   (b) the sum of the standard scores of these abilities?
   (c) growth in each of the three abilities?
   (d) growth in the sum of the standard scores of these abilities?

(3) What is the relationship between reading ability and:
   (a) each of the three abilities?
   (b) the sum of the standard scores of the three abilities?
   (c) growth in each of the three abilities?
   (d) growth in the sum of the standard scores of the three abilities?

The three specific abilities presented above, which were assumed to be most representative of the ability to infer, and which therefore served as the basis for the experimental classroom procedures and for the construction of the evaluating instruments, were selected as a result of an exhaustive analysis of the factors involved in scientific thinking and in the ability to make conclusions.

SCOPE AND MATERIALS

The experimental phase of the study was conducted at the Christopher Columbus High School, Bronx, New York, using as subjects approximately 550 students in the incoming ninth-grade class. The Henmon-Nelson Test of Mental Ability, Form A, was used to determine the mental ability of the students. The students' reading abilities were judged by reference to the permanent record cards and interpreted as reading grade equivalents. The ability to make conclusions was tested by a battery of instruments constructed by the author. This battery consisted of three sections, designed to measure, respectively:

(a) the ability of the student to make a conclusion from data in a paragraph, and to write it in his own words. This test was designated as Form A.
(b) the ability of the student to select the best conclusion for certain data from four proposed conclusions, designated as Form B.
(c) the ability of the student to indicate the correct reason for a faulty conclusion proposed for data in a paragraph, when various reasons are suggested. (Form C)

The reliability of the tests was determined by the split-half method and gave indices of reliability of .88, .88, .68, and .91 respectively for Forms A, B, C, and for the total test. The validity of the test was established by unanimous agreement of a jury of three prominent educators in the field, by item analysis to determine the discriminatory power and difficulty of the test items, and by intercorrelation. The jury also approved the scoring scale used in rating the answers to Form A and the acceptable answers for Forms B and C.

The battery of tests used in the investigation is presented at the end of this report.

Five classes taught by the investigator and three classes taught by another instructor were designated as the experimental group. The remaining twelve classes in first-term general science, taught by five other members of the department, were designated as the control group. The

groups were evenly matched by means of scores on the test of mental ability and the sum of the standard scores on the tests for ability to make conclusions.

The subject matter studied was that usually included in the first term's work in general science at the school, the factual content being the same for both the experimental and the control groups. Three units were studied, " Air," " Water," and " Food."

PROCEDURE

During the first week of the September, 1942, school term, the entire incoming group was given the mental test and the test in the three aspects of the ability to make conclusions. The classes selected as the experimental group received a type of instruction which sought to emphasize the abilities to make original generalizations, to select the best conclusion from among several suggested, and to select the best reason for a faulty inference. Each lesson started with a clearly established problem. The teacher then proceeded, by experiment or other means, to present the facts necessary for the solution of the problem. A record of the steps of the experiment (problem, procedure, and observation) was kept on the blackboard and in the students' notebooks. Where the facts needed for the solution of the problem could not be obtained by classroom demonstration, the necessary facts and the sources were listed in lieu of procedure and observation. Each student was then asked to make a conclusion in his own words and to write that conclusion in his notebook. Four or five students were then sent to the blackboard to write their conclusions, and the class discussed and then rated and evaluated these in terms of some or all of the following criteria:

(1) Does the conclusion answer the proposed question or problem?
(2) Does the conclusion agree with the facts of the experiment?
(3) Does the conclusion agree with your own outside experiences?
(4) Are there enough facts to make the conclusion valid?
(5) Are the data obtained by proper control in the experiment?
(6) Is the conclusion clearly expressed?

The best conclusion on the basis of the data and other pertinent experiences was then selected by the class for inclusion in their notebooks, directly under their own initial conclusions. Three class hours were used at the beginning of the term to outline the essentials of scientific procedure, at the end of which the above criteria were presented as " checks " on a conclusion. These were written in the students' notebooks and referred to when necessary.

A typical lesson will serve to illustrate the procedure. The unit on " Water " included work on flotation. After suitable motivation, the problem " When will objects float in water? " was elicited and written on the blackboard and in the students' notebooks. A demonstration was then performed in which various objects were weighed in air, then completely submerged in water and the displaced water collected and weighed. The data obtained were tabulated and recorded. The pupils were then asked to write their own conclusions, the teacher making certain that each student made a serious effort to derive some inference from the data. Several students were then selected at random to write their statements on the board. Some of the responses actually given for this problem were:

Heavy objects sink, light objects float.
An object floats when it weighs less than water.
Objects weigh more in air than in water.
An object floats in water when it does not weigh as much as the water it displaces.
Lead sinks, wood floats.

The class then proceeded to eliminate the invalid conclusions by application of the criteria. The first statement was eliminated upon reference to the facts of the experi-

ment, as well as the students' own experiences. The third was eliminated because it did not answer the problem. The last conclusion presented was found unsuitable because there were not sufficient facts to make the conclusion valid. This left the second and fourth inferences, which to many of the students appeared equally correct. The fourth inference, "An object floats when it weighs less than the water it displaces," was finally selected by the students as representing the most accurate conclusion, and this was written in the students' notebooks.

Frequently more than one of the responses was acceptable upon application of the criteria, and in such cases the class was asked to select the one which was most clearly expressed. Where the class could not arrive at a valid inference as a result of its own thinking, sufficient additional evidence was presented to assist the group in arriving at a logical generalization. The investigator and his assistant were particularly careful to avoid making conclusions for the students.

The teachers in the control group were asked to adjust their teaching procedures so that they did not conflict with the characteristic factor of the experimental teaching procedure. It was definitely ascertained that these teachers were not counteracting the experimental factor, in that they were not emphasizing the method of selection and evaluation of conclusions used with the experimental group.

At the conclusion of the experiment in January, 1943, all students in both groups were again given the battery of tests in the ability to make conclusions.

FINDINGS

The significant findings are presented in Tables I, II, and III, and may be summarized as follows:

(1) Both the experimental and the control groups made very appreciable gains in mean scores on the final tests of ability to make conclusions, as compared with scores on the initial tests.

(2) The means of the scores on the final tests on ability to make conclusions, for the experimental group, were significantly higher than the means of the scores attained by the control group, the differences being: for Form A, 3.80σ; or Form B, 2.43σ; for Form C, 6.68σ; for the complete battery, 5.21σ.

(3) The coefficients of correlation between scores on the test of mental ability and scores on the pretests of ability to make conclusions were, for Form A, .62; for Form B, .55; for Form C, .43; and for the battery, .65. The coefficients of correlation between scores on the mental test and differences between scores on the mental test and differences between scores on initial and final conclusions tests (growth in the ability) were, for Form A, —.02; for Form B, .00; for Form C, .07; and for the total test, .04.

TABLE I

MEANS AND STANDARD DEVIATIONS OF SCORES ON INITIAL AND FINAL TESTS OF ABILITY TO MAKE CONCLUSIONS FOR CONTROL AND EXPERIMENTAL GROUPS

	Control Group			*Experimental Group*		
Initial Tests	*N*	*Mean*	*S.D.*	*N*	*Mean*	*S.D.*
Form A	225	19.16 ± .37	8.25 ± .26	225	18.90 ± .36	8.01 ± .25
Form B	225	15.65 ± .21	4.62 ± .15	225	15.73 ± .20	4.47 ± .14
Form C	225	7.04 ± .11	2.42 ± .08	225	6.93 ± .11	2.52 ± .08
Total*	225	0.02 ± .11	2.36 ± .08	225	0.00 ± .11	2.38 ± .08
Final Tests						
Form A	217	27.28 ± .38	8.25 ± .27	219	29.95 ± .36	7.83 ± .25
Form B	221	19.81 ± .20	4.32 ± .14	210	20.86 ± .19	4.00 ± .13
Form C	213	8.01 ± .12	2.64 ± .09	211	9.57 ± .12	2.56 ± .08
Total*	203	−0.58 ± .11	2.49 ± .08	197	+0.65 ± .11	2.43 ± .08

* Scores for the total test are given as sigma scores.

(4) The coefficients of correlation with reading ability were of similar magnitude. The correlations of reading grades with scores on the initial tests on ability to make conclusions were .59, .50, .41, and .61 respectively for Forms A, B, C, and the total test. The coefficients of correlation between reading grades and differences between scores on initial and final conclusions tests were —.11, .07, .05, and .01 respectively for Forms A, B, C, and the entire battery.

TABLE II

COEFFICIENTS OF CORRELATION BETWEEN SCORES ON HENMON-NELSON TEST OF MENTAL ABILITY AND INITIAL SCORES ON THE CONCLUSIONS TEST, AND BETWEEN SCORES ON THE MENTAL TEST AND DIFFERENCES BETWEEN SCORES ON INITIAL AND FINAL CONCLUSIONS TESTS.

(N = 552 throughout)

Test	*Correlations of Mental Test Scores with Initial Conclusions Test Scores*	*Correlation of Mental Test Scores with Differences between Scores on Initial and Final Tests*
Form A....	.62 ± .02	—.02 ± .03
Form B....	.55 ± .02	.00 ± .03
Form C....	.43 ± .02	.07 ± .03
Total ..	.65 ± .02	.04 ± .03

TABLE III

COEFFICIENTS OF CORRELATION BETWEEN READING GRADES AND SCORES ON THE INITIAL CONCLUSIONS TESTS, AND BETWEEN READING GRADES AND DIFFERENCES BETWEEN SCORES ON INITIAL FINAL CONCLUSIONS TESTS.

(N = 493 throughout)

Test	*Correlation of Reading Grades with Scores on Initial Conclusions Test*	*Correlation of Reading Grades with Differences between Scores on Initial and Final Tests*
Form A....	.59 ± .02	—.11 ± .03
Form B....	.50 ± .02	.07 ± .03
Form C....	.41 ± .03	.05 ± .03
Total ..	.61 ± .02	.01 ± .03

CONCLUSIONS

(1) A teaching technique which emphasizes the ability to make conclusions, to judge conclusions, and to state reasons why some conclusions were faulty was found to produce significantly higher scores on tests for some aspects of the ability to make conclusions, among ninth-year general science students in a large city high school, than did teaching techniques which did not emphasize these abilities.

(2) Students with high mental ability are more likely to show initial skill in the ability to make conclusions than are those with poorer mental development.

(3) Students with good reading ability are more likely to show initial skill in the ability to infer than are those not so well able to read.

(4) Mental ability and reading ability are very poor indications of the ability to improve one's skill in making conclusions.

(5) The ability to state a conclusion, the ability to select the best reason for a faulty conclusion, and the ability to select the best conclusion from among several presented, are not identical abilities.

EDUCATIONAL IMPLICATIONS

It has been said that the primary function of education is to promote the general welfare by helping each individual to develop his best social and personal competence. Critical thinking is high on the list of cardinal objectives necessary for the attainment of this ideal. Unfortunately, the tendency has been to follow the path of least resistance and emphasize the easily measurable objectives, at the expense of others which may be as important, or even more so. It has been shown here that a teaching technique directed toward the attainment of a specific objective (the ability to make conclusions) can produce considerable improvement in this ability among students. Certainly there should be no bar to the integration of this and similar types of instruction with the more "formal" routines of the classroom. The nature, content, and procedures of science seem to be particularly well adapted to the utilization of these techniques. It should be realized, however, that the best results will be obtained by directing teaching procedures toward the objective desired, rather than by dependence on the concomitant

outcomes obtained by emphasis on the factual content of science. In other words, if a particular objective is to be attained, the techniques of instruction should be directed toward the attainment of that specific outcome.

The fact that the students in the lower percentile of mental and reading ability were able to improve in the ability to make conclusions, apparently as a result of the type of instruction used, is particularly significant. To what extent are we failing students on the basis of lack of ability to recall facts, or lack of reading ability, or other factors which are readily assayed, when they may be making definite improvement in other aspects of competence which we make no attempt to measure? To what extent will a revision of our classroom objectives and teaching procedures make possible the better realization of the potentialities of all our students? The basic function of education implies that our efforts be directed toward the solution of these and similar vital problems.

The function of evaluation is to determine to what extent the objectives of education are being realized. Since the objectives of education involve more than the accumulation of a body of knowledge, greater attempts should be made to test for the no longer "intangible," non-factual outcomes of education. It is conceded that the construction of a test of high validity and reliability is a tedious process, but it is felt that questions of the type used in this research may be utilized very effectively in the day by day work of the classroom. A test need not be standardized to function as an aid to teachers and students in the guidance of learning. More extensive use and refinement of tests designed to measure one or more of the abilities related to scientific method may eventually result in sufficient objectivity and confidence to permit of evaluation and rating of students in terms of this important objective.

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TEST ON ABILITY TO MAKE CONCLUSIONS—FORM A

Directions: In each of the statements which follow you are given some facts which may be discovered by means of experiment. From these facts it is possible to make a conclusion and so answer the question at the end of each statement. Read each statement carefully, and write your answer *in complete sentences.*

Example: An inflated basket-ball was balanced on a scale. When the air was released from the basket-ball, the ball seemed to be lighter. What does this show? *Answer:* Air has weight.

Items:

1. A student planted some bean seeds in each of two bottles containing soil. One bottle was closed with a stopper, while the other was kept open. The temperature and amount of moisture in both bottles remained the same. Only the bean seeds in the open bottle continued to grow. What does this show?

2. In order to find the weight of water, a student first weighed an empty gallon bottle and found that it weighed 1 pound, 12 ounces. He then filled the bottle with water and weighed it again, and this time it weighed 9 pounds, 12 ounces. What does this show?

3. Plants are able to manufacture starch in their green leaves. A plant was kept in the

dark for a few days. Some of its leaves were then covered with black paper and the plant was placed in the sunlight for a day. Tests then showed that all the leaves contained starch, except those that were covered. What does this show?

4. Whenever a magnet is moved in a coil of wire, an electric current is produced. A student used different size coils with the same magnet and got the following results:

Coil	*Electricity produced*
100 turns	3 volts
500 "	15 "
1000 "	30 "
2000 "	60 "

What does this show?

5. Whenever a magnet is moved in a coil of wire, an electric current is produced. A student used a coil of wire and magnets of different strengths and got the following results:

Strength of magnet	*Electricity produced*
1 X	8 volts
2 X	16 "
3 X	24 "
4 X	32 "

What does this show?

6. A wire becomes heated when an electric current flows through it. A student passed different amounts of electricity through a wire and got the following results:

Amount of current	*Effect on wire*
1 ampere	warm
2 amperes	orange heat
3 "	yellow heat
4 "	white hot
5 "	wire melts

What does this show?

7. A student weighed various objects in air and again in water, and obtained the following results:

Object	*Weight in air*	*Weight in water*
Stone	100 ounces	70 ounces
Lead	250 "	225 "
Brass	25 "	22 "
Wood	45 "	33 "

What does this show?

8. Whenever carbon is burned in oxygen, the gas carbon dioxide is formed. A diamond was burned in oxygen and all of it was turned to carbon dioxide. What does this show?

9. A scientist heated various metals in air, allowed them to cool, and compared their weights before and after heating. He got the following results:

Metal	*Weight before*	*Weight after*
Zinc	55 ounces	81 ounces
Copper	128 "	158 "
Aluminum	54 "	102 "
Lead	207 "	223 "

When he repeated the experiment in a vacuum (no air) no change in weight took place. What does this show?

10. An aviator took a barometer (an instrument which measures air pressure in inches of mercury) with him on a plane trip. He compared the barometer with his altimeter (which measures height) and noticed the following:

Altimeter	*Barometer*
ground level	30.0 inches
900 feet	29.0 "
1800 "	28.0 "
5400 "	24.0 "
9000 "	20.0 "

What does this show?

11. A student was given three unlabelled bottles, one of which contained the gas nitrogen, another the gas oxygen, and the third the gas carbon dioxide. He knows that a wooden splint burns in oxygen, but not in nitrogen or carbon dioxide. He also knows that limewater turns a milky color when mixed with carbon dioxide, but not with oxygen or nitrogen. How can he tell which bottle contains the gas nitrogen?

12. When a wire is heated in air or oxygen the wire burns. In an electric lamp, the wire is heated white hot, but does not burn. What does this show?

13. A student placed thermometers in light soil and in dark soil and noticed that they both read 68° F. He then placed the containers with the soil in the sunlight for an hour. The thermometer in the light soil was now at 72° F., and the thermometer in the dark soil was at 85° F. What does this show?

14. Plants manufacture starch in their leaves with the aid of sunlight. A plant with partly green and partly white leaves was placed in the sunlight for a few days. Tests then showed that the green parts of the leaves contained starch, but that the white parts did not contain starch. What does this show?

15. A student learned in his science class that oxygen is the gas which helps things burn. He placed a burning splint in a bottle of air and noticed that it burned normally. He then collected a bottle of exhaled air and placed a burning splint in that bottle. The splint was extinguished. However, a piece of yellow phosphorus, which burns very easily in air, continued to burn for some time in the exhaled air. What does this show?

16. A student prepared oxygen by heating a mixture of the substances potassium chlorate and manganese dioxide. He then tried heating potassium chlorate alone and found that he got oxygen, but more slowly and at a higher temperature. When he heated the manganese dioxide alone to the same temperature, he did not get any oxygen. What does this show?

TEST ON ABILITY TO MAKE CONCLUSIONS—FORM B

Directions: In each of the statements below an experiment is described and some possible answers are suggested. Select the one which you think is the best conclusion on the basis of the facts presented.

Items:

1. When iodine is added to starch, a blue black color is formed. Some iodine was added to milk, and the color became yellow. This shows that:

(a) Milk contains sugar.
(b) Milk contains starch.
(c) Iodine can not be used to test for starch in milk.
(d) Milk does not contain starch.

2. A student placed a bar magnet in a pile of iron filings and noticed that most of the filings were held at the ends of the magnet, with few filings in the center. This would show that:

(a) Magnets attract iron filings.
(b) The ends of a magnet are called the poles.
(c) Horseshoe magnets are stronger than bar magnets.
(d) Magnetism is strongest at the ends of a bar magnet.

3. A student packed some paper into a test tube and heated it strongly. The paper burned only at the opening of the test tube. This indicates that:

(a) Paper can burn.
(b) Paper must be heated in order to burn.
(c) Paper needs air in order to burn.
(d) Paper can burn without air or oxygen.

4. When the gas hydrogen is mixed with air and ignited, an explosion takes place and water is formed. A student mixed some illuminating gas with air in a bottle and ignited it. An explosion took place and drops of water formed on the inside of the bottle. This seems to indicate that:

(a) Illuminating gas can burn.
(b) Illuminating gas contains water.
(c) Illuminating gas is hydrogen.
(d) Illuminating gas contains hydrogen.

5. A student placed a geranium plant under a bell jar and filled the jar with the gas carbon dioxide. He placed a burning splint in the jar and the flame was extinguished. He sealed the jar completely, and placed it, with the plant, in the sunlight. The next day he again inserted a burning splint and this time it continued to burn. He knows that the gas oxygen helps burning. This would show that:

(a) Plants use carbon dioxide.
(b) The carbon dioxide escaped.
(c) The flame was extinguished by the carbon dioxide.
(d) Plants use carbon dioxide and give off oxygen.

6. When an artery is cut the bleeding may be stopped by tying a tourniquet (a tight bandage) between the cut and the heart. This is evidence that:

(a) Blood in an artery is flowing away from the heart.
(b) Arterial bleeding is dangerous.
(c) When an artery is cut, it will bleed.
(d) Blood in the arms and legs flows downward.

7. A funnel covered with a sheet of rubber was immersed in a jar of water. The pressure of the water caused the rubber sheet to bend inward. The deeper the funnel was immersed into the water, the more the rubber sheet was bent inward. This would show that:

(a) The greater the depth, the greater the pressure of water.
(b) Water exerts pressure.
(c) Rubber is more elastic in water than in air.
(d) Pressure is exerted in all directions.

8. A student was trying to find out why some objects sink and others float in water. He weighed many objects, first in air, and then by means of a special apparatus, collected and weighed the water which the object displaced. These are his results:

Object	*Weight in air*	*Weight of displaced water*	*Floats or sinks*
Stone	150 ounces	50 ounces	sinks
Cork	10 "	30 "	floats
Iron	140 "	10 "	sinks
Wood	150 "	200 "	floats
Lead	150 "	10 "	sinks

From these facts he should conclude that:

(a) Lead and iron sink; wood and cork float.
(b) Substances weighing less than 100 ounces will float.
(c) An object will float if it weighs less than the water it displaces.
(d) An object will float if it takes up a large amount of space.

9. A student burned various amounts of the gas hydrogen in oxygen. He noticed that in each case pure water was formed, and sometimes oxygen or hydrogen remained. These were his results:

Oxygen	*Hydrogen*	*Substances left*
20 pints	40 pints	water only
150 "	150 "	water + 75 pints oxygen
40 "	100 "	water + 20 " hydrogen
100 "	200 "	water only

This is evidence that:

(a) Oxygen is necessary for burning.
(b) Water is made up of two volumes hydrogen to one volume oxygen.
(c) Water is made up of oxygen and hydrogen.
(d) Water is made up of two gases.

10. The gas carbon dioxide turns limewater milky. A student burned a piece of wood in each of two bottles. Then he placed some water in one of the bottles and some limewater in the other bottle, and shook both. Nothing happened to the water, but the limewater turned milky. This shows that:

(a) Carbon dioxide was present in the bottle.
(b) The piece of wood contained carbon dioxide.
(c) Carbon dioxide is formed when wood burns.
(d) Carbon dioxide turns limewater milky.

11. A student placed various burning substances in bottles of air, oxygen, and a third bottle of air from which all the oxygen had been removed. The substances burned normally in the air, burned very brightly in the oxygen, and went out immediately in the third bottle. This is evidence that:

(a) Substances burn brightly in oxygen.
(b) Air is necessary for burning.
(c) Air contains oxygen.
(d) The oxygen in the air helped these things burn.

12. A student placed an open bottle of air mouth to mouth over an open bottle of hydrogen gas. After one minute, he tested and found that both bottles contained hydrogen. He then placed an open bottle of hydrogen over an open bottle of air. Tests showed that after one minute only the upper bottle contained hydrogen gas. This is evidence that:

(a) Hydrogen burns in air to form water.
(b) Hydrogen gas is heavier than air.
(c) Hydrogen gas is lighter than air.
(d) Gases intermix with each other.

13. A science student read that a thermite incendiary bomb will burn under water or sand, and cannot be extinguished. He knows that oxygen is necessary for burning. He could therefore conclude that:

(a) The thermite bomb does not use oxygen.
(b) Special methods are required to extinguish incendiary bombs.
(c) A spray of water will put out a thermite bomb.
(d) A thermite incendiary bomb carries its own supply of oxygen.

14. A scientist was examining some tiny living cells under a microscope. By means of a delicate needle, he was able to cut apart each cell. He found that when he cut the cell through the nucleus both parts survived. When he cut through the cell away from the nucleus, the part which retained the nucleus lived, and the other part died. This shows that:

(a) The nucleus is an important part of the cell.
(b) Microscopic cells can be dissected.
(c) Microscopes are needed to study cells.
(d) All living things contain cells.

15. A student placed some fruit flies in a test tube, stoppered the test tube, and covered one half of it with black paper. When he placed a light near the test tube the fruit flies all came to the part which was not covered. This seems to show that:

(a) The fruit flies are attracted by light.
(b) All insects are attracted by light.
(c) The fruit flies were trying to get air.
(d) They were trying to escape through a hole in the stopper.

16. Fish need oxygen in order to live. Fish placed in a tank of water containing plants continue to live, but fish placed in plain water will die after a few days. This would indicate that:

(a) The plants supply the fish with oxygen.
(b) Fish need oxygen in order to live.
(c) There is something in water which kills fish.
(d) Fish in water with plants do not need oxygen.

17. A student was trying to find what chemical elements make up paper. He burned some paper and found that the gas carbon dioxide (which contains the elements carbon and oxygen) and water vapor (which contains the elements hydrogen and oxygen) were formed. When he heated some paper in a test tube, water vapor was given off and the element carbon remained. This would seem to show that:

(a) Paper contains the elements carbon and water vapor.
(b) Paper contains carbon dioxide and water vapor.
(c) Paper contains the elements carbon, hydrogen, and oxygen.
(d) Paper can burn.

18. The weight of a substance is due to the attraction of gravity between that substance and the center of the earth. The greater the distance between the object and the center of the earth, the less the force of gravity. Objects weigh slightly more at the Poles of the earth than they do at the Equator. This is evidence that:

(a) Special scales must be used to get accurate weights.
(b) The less the weight, the less the attraction of gravity.
(c) The earth is not a perfect sphere, but is flattened at the Poles.
(d) The Equator is nearer the center of the earth than are the Poles.

19. In the year 1590 a famous scientist tried the experiment of dropping a ball of iron and a ball of wood, both of the same size, at the same instant from a high tower. He repeated the experiment many times and each time noticed that they hit the ground at exactly the same time. This shows that:

(a) They both fell at the same speed.

(b) The experiment was faulty, since the iron ball should have landed first.
(c) The wood ball was slowed up by the air.
(d) The speed with which the objects fell did not depend on their weight.

20. A student found by experiment that a magnet can attract iron, steel, and nickel, but can not attract aluminum, tin, copper, and brass. He tried the magnet on a tin can, and found it was attracted. This would seem to show that:

(a) The tin can is made of steel.
(b) Impure tin can be attracted by a magnet.
(c) The tin can contains nickel.
(d) The tin can is not made entirely of tin.

21. A student placed some steel wool in a moistened test tube and inverted it over a jar of water. The next day he noticed that some water had risen into the test tube, and that the steel wool had become rusty. The water did not rise in another inverted test tube in which there was no steel wool. The best conclusion he can make from these facts is:

(a) When steel rusts, it gives up oxygen.
(b) When steel rusts, it uses up some part of the air.
(c) Steel wool can rust.
(d) Water will rise in an inverted test tube.

22. A famous scientist once discovered that when he made the gas nitrogen by one method, a certain amount always weighed exactly 1.2505 grams. When he prepared it by another method, the same amount of nitrogen always weighed 1.2572 grams. This would indicate that:

(a) Nothing, since the results are close enough.
(b) The scales used for weighing were not sufficiently accurate.
(c) The nitrogen made by the second method was mixed with some heavier gases.
(d) The weight of the nitrogen changes from time to time.

23. A scientist studied the distances which objects fall in certain times, and got the following:

Time	*Distance fallen*
1 second	16 feet
2 seconds	64 feet
5 seconds	400 feet
10 seconds	1600 feet

The best conclusion he can make is:

(a) The greatest speed with which objects can fall is 160 feet per second.
(b) Distance fallen in feet equals 16 × seconds × seconds
(c) At the end of each second, the speed is increased 16 feet per second.
(d) When objects fall, they constantly increase their speed, up to a certain point.

24. A student measured the intensity of light which he received at various distances from a lamp and tabulated his results as follows:

Distance from lamp	*Intensity of light*
8 feet	1 foot-candle
4 "	4 foot-candles
2 "	16 "
1 foot	64 "

His best conclusion is:

(a) The greater the distance from the lamp, the less the light received.
(b) Doubling the distance from the lamp decreases the amount of light by one-fourth.
(c) Doubling the distance from the lamp increases the amount of light four times.
(d) The intensity of illumination is measured in foot-candles.

25. When different kinds of food are burned, the gases carbon dioxide and water vapor are formed, and heat and light are given off. We exhale more carbon dioxide and water vapor than we inhale, and our bodies are always warm. This indicates that:

(a) We breathe in oxygen and breathe out carbon dioxide.
(b) A process similar to burning takes place inside our bodies.
(c) A process exactly like burning takes place inside our bodies.
(d) Foods provide us with energy.

26. A student planted different types of seeds in five large pots. Two of these pots contained good soil and the other three contained the same soil but with all potassium salts (a type of mineral) removed. All plants received the same treatment. The plants in the normal soil flourished and developed fully, but the plants in the other three pots were very small and eventually died. This would seem to show that:

(a) Plants need potassium salts in order to begin growth.
(b) The plants needed more soil.
(c) Potassium salts absorb water.
(d) Potassium salts are necessary for the full development of the plants.

27. A spectroscope is an instrument which enables us to detect the different elements by means of the characteristic colored lines which they produce when heated. In 1868, a scientist studied the light given off by the sun with a spectroscope and discovered a series of colored lines which did not correspond with any element known on earth. This made him conclude that:

(a) There was an element on the sun which did not exist on earth.
(b) The sun is extremely hot.
(c) The sun contains elements.
(d) The spectroscope is a useful instrument.

28. In 1781, William Herschel discovered the planet Uranus. Astronomers carefully calculated the path which this planet should follow around the sun, and other astronomers followed the movement of this planet with their telescopes. After 60 years, it was noticed that Uranus was

actually farther from the sun than had been predicted. They knew that the force of gravity causes all objects to attract each other. This was evidence that:

(a) The astronomers made their calculations incorrectly.
(b) The telescopes needed improvement.
(c) Another planet, farther from the sun, was attracting Uranus.
(d) Uranus is a planet and not a star.

29. A student tried to make electricity by placing metals in different acids. His results follow:

Procedure	*Observation*
copper in sulphuric acid	nothing happened
copper and zinc in nitric acid	electricity made
copper and zinc (no acid)	nothing happened
copper and iron in sulphuric acid	electricity made
zinc and lead in sulphuric acid	electricity made

The best conclusion he can make is:

(a) Electricity can be produced by placing two different metals in an acid.
(b) Copper is necessary for making electricity.
(c) Electricity will make a bell ring.
(d) Sulphuric acid is necessary for making electricity.

TEST ON ABILITY TO MAKE CONCLUSIONS—FORM C

Directions: Read this very carefully. Your teacher will explain any part of these instructions which you may not understand.

Whenever scientists are faced with a problem they seek facts to help in its solution. These facts, when properly analyzed and studied, may help them in reaching a conclusion, or answer, to their problem. However, any conclusion that is reached must be carefully checked before it can be accepted. The following four statements show some ways in which a conclusion may be faulty:

(a) It does not answer the problem or question.
(b) It does not agree with the facts of the experiment.
(c) There are not enough facts to make the conclusion valid (correct).
(d) The facts have not been obtained by proper control (comparison) in the experiment.

Below are described certain experiments, each of which has a *faulty* conclusion. You are to determine which of the above four statements is the best reason for its being false.

Example A: A student wanted to find which was heavier, milk or cream. He found that a bottle filled with cream weighed 1 pound, 4 ounces, while the same bottle filled with milk weighed 1 pound, 6 ounces. He concluded that cream is heavier than milk.

In this case, his conclusion does not agree with the facts of the experiment. The answer is (b).

Example B: A doctor discovered a chemical which he thought would cure pneumonia. He tried the chemical on 50 patients, and found that 45 recovered and 5 died. He decided that the chemical would be able to cure pneumonia.

The doctor's conclusion is faulty because he cannot be sure that the patients would have recovered even without the use of his chemical. He has no control, or comparison. The answer is (d).

Items:

1. A student wanted to find out if all foods contained starch. He tested ten different foods and found that they all contained starch. He concluded that all foods contained starch.

2. A student wanted to find the amount of oxygen in the air. He covered a burning candle with a bottle and left another burning candle uncovered. The flame went out in the candle that was covered, but the other candle continued to burn. He concluded that oxygen is necessary for burning.

3. A student wanted to test an unknown gas for nitrogen. He placed a flaming splint in a bottle which he knew contained nitrogen and found that the splint was extinguished. He placed another flaming splint in the bottle with the unknown gas and that was also extinguished. He was then sure that the unknown gas was nitrogen.

4. A student trying to find why objects sink or float in water performed an experiment and got the following results:

Object	*Weight in air*	*Weight of displaced water*	*Sinks or floats*
Wood	100 ounces	120 ounces	floats
Lead	300 "	20 "	sinks
Aluminum	750 "	125 "	sinks
Cork	50 "	100 "	floats

His conclusion was that objects which displace a large amount of water will float and those which displace a small amount of water will sink.

5. A scientist wanted to discover whether a certain food contained starch. He found that whenever he mixed starch and iodine, a blue-black color was formed. He placed some iodine on a potato and a blue-black color was formed. He concluded that the food was fattening.

6. A student wanted to find whether saliva can change starch to sugar. He took a cracker which contained starch, but no sugar. He mixed the cracker with saliva and when he tested it again found that the cracker now did contain sugar and no starch. He concluded that the saliva changed the starch to sugar.

7. A student found a bar of steel which he thought was a magnet. He knew that a magnet attracts steel; that like poles of two magnets repel each other; and that unlike poles attract

each other. He placed a magnet near the bar of steel and found that it was attracted. He concluded that the bar of steel was a magnet.

8. A student wanted to discover why the roots of plants grow downward. He placed some small seeds on a piece of blotting paper and kept them in place with glass plates and rubber bands. He wet the top of the blotting paper and noticed that the roots of the growing seeds reached up. When he wet one of the sides, the roots grew toward that side. He concluded that the force of gravity pulls roots down into the earth.

9. A group of boys wanted to find out which of two pails of water was the hotter. They each tested the water with their fingers. Nine boys said that the water in pail A was hotter than that in pail B; one boy said that B was hotter than A. They decided that A was hotter than B.

10. A student wondered how flies were born. He recalled that he frequently saw garbage and rotted meat with flies around them. He concluded that the garbage produced the flies.

11. The students in a science class wanted to find out whether exhaled air contains any oxygen. The instructor told the class that a certain amount of oxygen is necessary in order for things to burn. He then placed a burning splint in a bottle of air and the class noticed that it burned normally. He next collected a bottle of exhaled air and placed a burning splint in that bottle. The splint was extinguished. The class concluded that exhaled air does not contain any oxygen.

12. A student was trying to find how to change the poles of an electromagnet. He made an electromagnet from a nail, some covered copper wire, and a battery. He found that the point of the nail was the N pole and the head of the nail was the S pole of the magnet. He noticed that when he changed the connections to the battery, the head of the nail became the N pole and the point of the nail became the S pole. He concluded that the point of the nail was always the N pole of the electromagnet.

13. A student was trying to discover whether a certain food contained Vitamin C, lack of which causes the disease scurvy. He gave the food to 50 guinea pigs and they all lost considerable weight. Loss of weight is one of the symptoms of scurvy. He concluded that the food did not contain Vitamin C.

14. A student wanted to determine which of several metals was the best conductor of electricity. He prepared silver, copper, iron, and aluminum wires of the same length and thickness, and measured the amount of electricity which each could carry. Here are his results: silver—6 amperes; copper—5 amperes; iron—1 ampere; aluminum—3 amperes. He concluded that iron was the poorest conductor of the group.

15. A student pilot was studying the lift of a wing section in a wind tunnel. He placed the wing at different angles, measured the lift produced, and tabulated his results as follows:

Angle of attack	*Lift*
0 degrees	1 pound
5 "	4 pounds
10 "	8 "
15 "	10 "
20 "	6 "

He concluded that the greater the angle of attack of the wing, the greater the lift.

IMPROVING READING IN ELEMENTARY SCIENCE

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BUSINESS, industry, and education for a long time, and more recently defense, have found the reading tool inadequate. The world outside the classroom judges the efficiency of reading by the results it produces when applied in specific areas. The failure of the reading tool to function satisfactorily is traceable to the instruction of pupils which concentrates on the means and rarely achieves its end, namely, application of the reading tool to the solution of problems of human living as found in the content subjects. Teachers are so concerned with fashioning and perfecting the tool that its functioning in its major role is lost sight of. How can the tool be improved, sharpened at one point, strengthened in another, unless its weaknesses are determined in the process of its application and modified accordingly?

Science in the elementary school affords unlimited opportunities for applying the reading skills. Determining children's weaknesses in this field and using them as

a guide to reading instruction will not only result in better comprehension but also in improved science understandings. The references on reading in elementary science which follow were selected for the contribution each makes toward helping a teacher improve pupil reading in science.

Among the suggestions offered in this literature for improving reading in science, several are fundamental. Of prime importance is an understanding of the function and kinds of reading required in science in order fully to utilize reading to achieve the purpose of science instruction. [9, 14] Investigators have found the problems of reading in science to be many, including those relating to number, to vocabulary, to understanding concepts, and to interpreting diagrams, charts, and pictures [10, 13]. Reading is only one of several classroom activities which help boys and girls develop science meanings. The others—namely, discussion, experimentation, observation, and excursions—are essential to developing a meaningful vocabulary and an understanding of the concepts of science, and consequently are basic to comprehension in science reading [2, 14].

A teacher of science, as is every teacher in the content fields, is responsible for teaching the vocabulary and reading skills of the subject [9]. No ready-made work sheets, practice exercises in skills, or vocabulary drills to help a teacher with a specific problem will be found in the literature. Instead, there is recommended the unit-type of instruction with guidance in reading activities in science [1, 11]. Such guidance includes classroom instruction designed to guide reading activities, mimeographed directions for study activities, and guides for study exercises [3, 12]. Reading exercises aside from those demanded by the regular work of the course are not suggested. The pupils are guided in the reading which they must perform to secure understandings of science materials. Experiments have shown that the unit-type of instruction with its guidance in reading improves the reading ability of pupils as well as extends their knowledge of science [1].

ANNOTATED REFERENCES ON READING IN ELEMENTARY SCIENCE

1. Beauchamp, W. L. "A Preliminary Experimental Study of Technique in the Mastery of Subject-Matter in Elementary Physical Science," *Studies in Secondary Education, I.* Supplementary Educational Monographs, No. 24, pp. 47–87. Chicago: Department of Education. University of Chicago, 1923.

   The purpose of the experiment was to determine the value of directed study as compared with undirected study of science material. Since the results favored the directed study group the teaching technique employed for this group in the experiment is one worthy of consideration for improving reading in science.

2. Blough, Glenn O. "Reading to Promote Understanding of Elementary Science Units," *Recent Trends in Reading.* Supplementary Educational Monographs, No. 49, pp. 240–245. Chicago: Department of Education, University of Chicago, 1939.

   Motivating science reading with experiences, such as excursions. field trips, experiments, and observation of animals, plants, and weather, aids in acquiring reading skills. Ways are suggested to extend pupils' vocabularies and achieve more meaningful reading.

3. Blough, Glenn O. "They Can't Read," *School Science and Mathematics,* 38:627–32, June, 1938.

   This article presents difficulties met by pupils in carrying out reading assignments in science. Examples of assignments from an actual classroom situation are analyzed and suggestions made for improving assignment. The importance of supervised study to determine the ability of class to read and to use this information to guide subsequent instruction and assignments is emphasized.

4. Bond, Guy L., and Bond, Eva. *Teaching the Child to Read.* New York: Macmillan Co., 1943. Pp. ix + 356.

   The authors analyze the difficulties encountered in science reading. In the discussion of these are examples of helpful teaching suggestions, such as anticipating or detecting difficulties, guiding instruction accordingly, and using first-hand experiences, pictures, and demonstrations to increase understandings.

5. Cole, Luella. *The Teacher's Handbook of Technical Vocabulary.* Bloomington,

Illinois: Public School Publishing Company, 1940. Pp. 119.

One of the vocabulary lists for thirteen school subjects included in this book is on general science. It comprises 261 of the essential elementary ideas (words) most commonly used in general science. Teachers may use this list of terms as a nucleus around which to organize their teaching and to teach the necessary concepts as they proceed with the explanation of subject matter.

6. Downing, Elliot R. *An Introduction to the Teaching of Science.* Chicago: The University of Chicago Press, 1934. Pp. vii + 258.

The importance of teaching pupils how to learn is stressed. This is an activity of the supervised study period in science during which time teachers should discover deficiencies in skills and teach each pupil how to overcome them. A few skills with teaching devices for developing them are enumerated.

7. Durrell, Donald D. *Improvement of Basic Reading Abilities.* Yonkers-on-Hudson, N. Y.: World Book Co., 1941. Pp. viii + 407.

A topic from a science textbook is used as an example for making an idea outline. A diagram shows the major and minor ideas in proper order and relationship. Other suggestions are given for developing skill in thorough reading.

8. Gordon, Dorothy. "Work-Type Reading in Third-Grade Science," *Newer Practices in Reading in the Elementary School.* Seventeenth Yearbook of the Department of Elementary School Principals. Bulletin of the Department of Elementary School Principals, Vol XVII, No. 7, pp. 369–371. Washington: Department of Elementary School Principals of the National Education Association, 1938.

The work-type reading skills practiced in this science unit were: choosing the main and subordinate topics for an outline, extending vocabulary, and remembering and reporting facts. The teaching procedure involved preparing reading materials at level of group, class reading and discussion of selection, and choosing topics for paragraphs, all under teacher supervision. The method proved effective in developing and reviewing work-type reading skills.

9. Heiss, E. D., Obourn, E. S., and Hoffman, C. W. *Modern Methods for Teaching Science.* New York: The Macmillan Co., 1940. Pp. x + 351.

Basic to the development of effective reading habits in science is a knowledge of reading difficulties as well as of science. The authors list five types of reading encountered in science. A recognition of these types of reading makes it possible to give more helpful guides to pupil lesson preparation and also to set different exercises which call for the use of the skills involved in the particular type of reading. Suggestions are given for the use of the table of contents, key works, bold-faced type, underlining, pictures, graphs, and tables.

10. Luthi, Loren R. "A Case Study of Reading Comprehension Difficulties in Science Materials," *Science Education,* 25:255–260, October, 1941.

The purpose of this study was to discover some of the comprehension difficulties which eighth-grade students experience in reading science material. Most common among the fifteen difficulties listed are those relating to vocabulary, punctuation, verbalism, and number. Helpful recommendations are given for overcoming these difficulties.

11. McCallister, James M. "Guiding Pupils' Reading Activities in the Study of Content Subjects," *Elementary School Journal,* 31:271–284, December, 1930.

An investigation by the author of reading difficulties encountered by pupils in Grades 7–8 in studying American history, mathematics, and general science disclosed the need for five types of guidance in reading. Such guidance may take the form of group instruction or of individual training. Under the former, suggestions and descriptions of procedures and devices in science are given which have resulted in noteworthy improvement in the five areas of reading difficulties.

12. McCallister, James M. *Remedial and Corrective Instruction in Reading.* New York: D. Appleton-Century Co., 1936. Pp. xviii + 300.

In Chapter XIV, "Guiding Reading Activities in the Study of Science," three phases of the problem are treated: (1) reading activities in studying science, (2) reading difficulties in studying science, and (3) suggestions for guiding reading activities. The guidance activities described illustrate an approach by which guidance in reading becomes a definite phase of the regular study activities of a course, without detracting effort from the regular class activities.

13. Parker, Bertha M. "Promoting Growth Through Reading in the Intermediate Grades," *Recent Trends in Reading.* Supplementary Educational Monographs, No. 49, pp. 246–254. Chicago: Department of Education, University of Chicago, 1939.

Difficulties met in reading science ma-

terials relate to vocabulary, construction, density of material, lack of background, and wrong attitude on part of reader. These may be overcome by guidance in science reading which consists of choosing or preparing suitable reading materials, building up appropriate experiential backgrounds, giving children a clear idea of what they are expected to gain from their reading, and giving help to children who show that they need it.

14. Parker, Bertha M. "Units Involving the Use of Reading Materials in the Middle Grades," *Co-Operative Effort in Schools to Improve Reading.* Supplementary Educational Monographs, No. 56, pp. 200–204. Chicago: Department of Education, University of Chicago, 1943.

    The article presents an analysis of the purposes of reading material in a science unit. Emphasis is placed on the fact that even though science reading material is easy—that is, the vocabulary is simple and the sentence structure and length make for easy reading—many concepts to be developed are difficult for children to grasp. To make more meaningful the reading material it should be supplemented with perceptual experiences such as experimentation, observation of natural phenomena, study of pictures, diagrams and models, and viewing films.

15. *Science Instruction in Elementary and High School Grades.* By Members of the Faculty of the Laboratory Schools of the University of Chicago. Chicago: Department of Education, University of Chicago, 1939. Pp. viii + 232.

    In the three representative units for intermediate science are procedures for integrating effectively reading materials, pictures, maps, models, and excursions for developing desired concepts, obtaining information, and building vocabulary. The work sheet which is a part of every unit affords opportunity through varied exercises, references, map and picture reading to develop work-type reading skills.

SYMPOSIUM: HOW CAN SCIENCE EDUCATION MAKE ITS GREATEST CONTRIBUTION IN THE POST-WAR PERIOD?

(Continued from the October issue)

I am assuming that the question means, how can science teachers—you, and you, and I—be most helpful to the people who will continue to live after the war? My answer to that is, by teaching to the best of our ability what mankind has learned about the nature of the world, the nature of man, and the nature of science so as to eradicate certain fears that have dogged man's steps or kept him cowering in his cave. These fears are our fear of hunger, our fear of sickness and death, our fear of strangers, our fear of ancient ghosts, and our fears of our own weaknesses.

Hunger.—The genus *Homo* might have survived in this hostile world of want as did other primates, by minding his own business, but not as well as the imagination of the species *sapiens* demanded. Men have engaged in progressively more elaborate variations, up to global wars, on the simple theme, wolf-eat-wolf. Aristotle considered slavery necessary for cultivating those distinctly human traits that set us above the beasts: Unless we were to revert to beastly living, we must either impound slaves or else devise mechanical substitutes. Science has furnished the machines to free all mankind from the work and status of slaves and from the fear of want. Science teachers can help by convincing people that there is no reason, outside ourselves, for retaining our various slaveries and our beastly living, along with our fear of want.

Sickness and Death.—Death is inseparable from life. Science has shown ways to strengthen and enrich life, as well as to lengthen it, and to remove some of its hardships and sufferings. Science can help further by directing men's thoughts and efforts away from traditional anxieties and misgivings about the demon death and his host of evil spirits, and toward making the most of life while it lasts. Science teachers can show people how to make the gains more widely available through those procedures by which science has made gains—joint efforts toward common ends, in contrast to competitive striving for private advantage.

Strangers.—Related to fear of want is fear of strangers, the potential enemies and potential rivals for the inadequacies. Science enables us all to have plenty of cake and ice cream (if that is what we want) without depriving any human being of anything he needs; yet we continue to deal with our neighbors as if they would grasp the bread from our children's mouths. Science teachers might help people understand that the potential abundance is to be had by the very processes that have made our science so potent, that is, by division of labor and pooling of talents across all barriers, natural and artificial. Science cuts across the ages as well as across nationalities and languages, races and religions, across all kinds of individual

differences. It uses both the dreamer and the man with the hoe. Science can help us open our minds to all kinds of people as well as to new ideas and strange ideologies. Science can teach us that the more of us there are working, the better off we all are, and so overcome hampering jealousies and suspicions. Science can teach people that science is itself a joint or social phenomenon through which individual genius is converted into common sense and common understanding, and eventually into common use for common welfare.

Ancient Ghosts.—By enabling more and more people and ideas to travel more rapidly and more extensively, science has enabled nearly everybody to discover how childish and absurd are the myths and superstitions of other people. But it has left most of us unaware of the scources and the ultimate fate of our own private gods and devils, and therefore still in fear of the ghosts that enslaved the spirits of our ancestors. Science has freed men from fear of lightning, which we have already harnessed. It can free men also from those hobgoblins they have invented to "explain" the workings of the world. Science teachers can help, however, not by denouncing superstitions and false beliefs, or by setting up a counterpropaganda, but by helping to clarify the processes by which man has raised himself above animistic fairy tales to the place where he uses hypotheses and experiments instead of relying an authoritarian dogmas sanctified in their complacency only by their antiquity.

Our Inadequacies.—It is only within our own times that we have been able, by means of the printed page, the radio and movies, to exchange over the entire world the thoughts and experiences and cultural resources of peoples historically separated in space and in outlook. These accelerated cultural exchanges have stirred millions into awed admiration of human achievement, while depressing them as individuals suddenly aware of their own limitations and worthlessness. We know more than ever about genetics but also more than ever how barren have been the opportunities of most individuals to fulfill the talents that they have. The severe demands which the war has made upon all our people, and especially upon those neglected youth of the thirties (just kept from fading out but kept also from sharing in our civilization), revealed dramatically the untapped resources latent in ordinary boys and girls of all classes of society, all races, all backgrounds. The accomplishments of these young people, admitted suddenly into our common life after but a brief training, are a token of what human beings can do under favorable conditions. Science teaching can help take the sting out of the frightened reproach that the use of reason makes man out to be "only an animal". Science can help millions identify themselves with the superiorities and dignities of mankind by getting them to take part jointly in the distinctly human process of making science—through wondering, thinking, guessing, trying out, and eventually mastering.

BENJAMIN C. GRUENBERG
New York City

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The critical contribution which science education should make to the post-war world is to habituate men, even the leaders of men, to scientific habits of thought. When the problems of social organization within a group, of relations between groups such as races or nations, of the selection of leaders in a group. are approached dispassionately and objectively, human affairs will move swiftly toward what all agree is the "better." For solution of these problems, as of those at simpler levels, must finally be reached by making the best possible guesses on the basis of existing facts, by performing social experiments suggested by such guesses, by carefully assaying the new facts generated from the experiment, and by making new and better guesses in the light of the new evidence.

Nor is it utopian to ask or hope for such rational behavior on the part of a people. The use of impersonal reason relative to prejudiced emotion and the use of altruism relative to selfishness are increasing in the course of human social evolution as they are in the greater sweep of all biological evolution. Nor is human nature irrevocably bound to its jungle ancestry; wise education, adequately applied, could revolutionize man's attitudes and behavior in a generation. These statements are necessarily dogmatic in this limited space; validation of them can be found in "Science Education and the Contemporary World", *Journal of Chemical Education.* 20:45, 1943.

The real problem is that of a wise and well-applied education, especially in science. Science has been taught in increasing intensity for a century, but man's thinking has been little altered. The thoughts and experiments of experts have remodeled his external world time after time, almost decade by decade, but with little of the desired internal changes. The trouble is that the spirit behind the result has not been taught. The sciences, their techniques, their data, their interpretations, are poured forth in a rising flood, mainly for prospective scientists; the attitudes and methodologies of science are rarely even examined, let alone experienced. By bringing research, as a way of behavior, into general science education these goals will be approached. And this, also, can be done—the evidence is in the article referred to. But it won't be, not adequately, until long after the early post-war period.

R. W. GERARD
University of Chicago

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A thorough understanding of basic principles and science concepts should continue to be one

of the main classroom goals. Men returning from the service—and many of them back in school again—will influence that emphasis. The training of these men has been intense and stripped down to very essentials. In the armed forces, as has been said, a man has to do a thing right the *first* time, or else! Time after time service men on furlough have said to me, "When we get back into school again we will be there for business—no more educational frills and sophomoric stuff for us." To be sure, the instructional materials and the learning activities used should reflect the times in which we live. The writer observed a physics class in a large city of his region recently. The students were reviewing basic concepts and their application. The method followed was that of identifying physical principles involved in the construction and operation of the airplane. The whole procedure was effective, spirited, and challenging.

Attitudes and skill in valid thinking will also continue to be of paramount inportance. We have given these objectives lip-service for a long time; now they should really *affect* learning procedures. The relationships that exist among men and nations are growing more complex and difficult all the time. Consequently, it is becoming increasingly hard for the average citizen to cope with problems such as the relation of capital and labor, the eugenic trend of the race, tax policies, federal planning in conflict with state rights, tariffs, race prejudices, and international relations. Yet, indirectly, intelligent votes must be cast on many of these issues if democracy is to continue. These questions can be settled only on the basis of pertinent facts and straight thinking.

Turning now to more specific contributions which science education can make in a post-war world, it is apparent, first, that proper emphasis will need to be placed upon the conservation of our natural resources. This should become a "must" in science education after the war. We are acting as "the arsenal of democracy" and under the conditions should be, but we are paying a terrible price for that distinction.

Second, science education can make a significant contribution in the future by accenting the study of health and recreation. This should be done as a special conservation measure. One of the large life insurance companies recently estimated that the cost of rearing a child whose father received $2,500 a year was $7,763. We can not afford, from the viewpoint of sound finances alone, to neglect such an investment. The present status of our national health may be judged somewhat from the fact that more than a million men have been rejected for physical and mental reasons by the selective draft boards of the country and almost a quarter of a million have been subsequently discharged from the service on similar grounds. As a nation we need to learn how to eat, rest, play, and work, so as to be mentally and physically fit and efficient.

FRANK C. JEAN
Colorado College of Education

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All education in our nation must adjust itself to the needs of required military training after the war is over. It is a practical certainty that able-bodied young men of college age will serve for a period that can hardly be less than one year.

Alert, ambitious high-school boys will gladly elect courses that prepare them for the more attractive branches of the armed forces. "During my year in uniform," many will say, "let Uncle Sam train me as a flyer." Others will reason, "I can become a radio expert during my year." Yet others will be attracted by the duties of engineers, meteorologists, photographers, machinists, and many other highly skilled and interesting specialties. For all of these, backgrounds of the sciences will be required. Motivation will be high. "You'll never fly if you flunk physics," will be strictly a statement of fact. Many of the most desirable military assignments will be open only to those who leap mathematical hurdles.

Certain of the new subjects, now taught as pre-induction courses, will be continued with organization for highest efficiency, abundant teaching materials, and assignment of the best teachers to these classes. As these new offerings crowd out some of the present topics in the high school curriculum, the losses may be borne with few if any tears.

We must not forget that high schools also instruct girls, and that in many technical branches of the armed forces—radio, range finding, light mechanical service, laboratories, weather observation, airport control, for example—women have proved their skill. Although in the past many girls, for reasons of their own, have avoided science and mathematics, it is likely that the motivation of attractive service in uniform will guide many of them into these subjects.

What will be the effect upon our nation as young people—both men and women—emerge by the hundreds of thousands each year from a period of military service in which they have become proficient in some practical branch of applied science? Many will wish to broaden their foundations in college courses. Others will seek employment in the skilled industries. Our nation, already great because of inventive resourcefulness, is sure to be transformed as a floodgate of technical skills and knowledge opens.

Even a conservative forecast of American life in the future is startling. It can never be the same America, in or out of school. The almost universal knowledge of some pure and much applied science will influence the attitudes and decisions of every consumer of our nation's

goods. A broadly based scientific point of view may develop that may indeed be termed a national philosophy! We would be amazed if we had full knowledge of the true impact of science and mathematics upon the privileges, the possessions—and the problems of future generations.

HANOR A. WEBB
George Peabody College for Teachers

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As a teacher and supervisor of biology and general science for the past forty years in the largest school system and for a part of that period in the largest high school in the world, I have been able to watch with great interest and no little misgivings the changing panorama of viewpoints and practices in science education. I now look back with a more or less nostalgic eye over a period of nearly fifty years and recall the several zigzag changes of front which have now brought us face to face with some serious post-war problems.

If this war teaches anything at all, it will lead us to believe that *thoroughness* is essential to success, that *discipline* is of great value both in mind and action, and that *simplified living* has its virtues. It follows that no namby-pamby, superficial, entertainment courses of study in any field should be tolerated in the post-war period.

Since the lack of thoroughness has always been one great weakness in our educational system, I would recommend a new method of approach to secondary education, which in my opinion has some distinct advantages in the light of our post-war problems. As a foundation I would suggest a four year core course in science, taught with the utmost thoroughness. The course, to be required of everyone, may be made up of general science, biology, physics, and chemistry, largely integrated and in proper sequence of topics and complexity, or it may preferably be a four-year course in general science (in the broad sense of the term) in which all of the above sciences plus geology, physiography, and even some astronomy, are fully integrated and presented in accordance with the psychological capacities of the pupils of each year of the high school. Such a course should not be considered in terms of how much ground is covered but of how well the limited ground chosen is covered. The course should use only enough facts in the work of the classroom, laboratory and field to furnish a sound basis for the formation of general concepts and the discovery of fundamental principles which can be used most effectively in explaining phenomena new to the pupil, in understanding new facts, and in solving the new problems which he will inevitably meet in the years to come.

Now it may be asked, why do you stress science as the required core course in the high school? The answer is simple. The kind of science I advocate, if properly presented, will put the pupil into immediate and intimate contact with his environment, both physical and social. And it will be by careful observation, experimentation, reflective thinking and the constant use of the scientific method that the well-being and happiness of oncoming generations will be assured. The supreme goal of all teaching about the environment should be the building of character. There is no subject or group of subjects better fitted to bring about this result than general science, a new science resulting from the synthesizing of which we have been wont to call the special sciences. To teach such a science content will be no easy matter. We may not now have the teachers who can do this work successfully, but we shall have them. We shall rise to the occasion. Of that I am sure.

GEORGE C. WOOD
James Monroe High School, New York City

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A fundamental assumption of all science is that this is an orderly, dependable universe, not a whimsical chaos. Discover the regular sequence of events here and now, the cause and effect relationship that invariably exists, and you may depend upon it that it is the same yesterday, today and forever.

Michael Faraday discovered the laws that an electric current flowing through a coiled wire makes a magnet of it and that a magnet moving into and out of a coiled wire induces an electric current in the wire. Then men applied these laws and built dynamos and motors, so harnessing, to do man's bidding, a mighty force which before had been only a source of terror. But the parts of these machines must be arranged in accord with the principles stated, not thrown together in any way that suits one's fancy.

Gregor Mendel discovered certain laws of heredity. And men have applied these to develop strains of wheat that will produce bumper crops even when they must endure severe winds, early frosts and partial drought. So, too, milch cattle have been bred that produce more than their own weight of butter in a year. But to accomplish these and similar remarkable feats one must conform to the laws.

The power house is set at the base of the dam, not on its top. The hot air furnace is located in the basement, not in the attic. The town water tank is built on a hill top, not in the valley. The law of fluid pressure dictates man's actions.

Science teaching should get this fundamental assumption over to the community so convincingly that it powerfully influences men's behavior. One must learn the laws of health and obey them if he does not want to suffer pain, defeat and premature death. He must learn the laws of straight thinking and conform to them if he is ambitious to be a leader rather than a slave. One must learn and obey the laws of moral integrity—the wisdom it has

taken ages of bitter experience to formulate—if he wants real happiness.

Research that discovers the laws of the universe is now so far ahead of individual and social practice that the teaching job of catching up to date is tremendous. We need not only to get over to Mr. Everyman an understanding of those laws most essential to individual and social welfare, but the laws must be so impressed that they will dictate wise behavior. Not only the fundamental principles of the natural sciences must be taught but also those of child care, mental hygiene, economics, sociology, ethics. Research in many fields knows enough of essential laws to make a better world. Mr. Everyman does not. His community is frankly disdainful of them. Only a program of continuous education as well as more thorough child education can successfully cope with the situation; and all the educational agencies—home, school, church, publishers, radio—must be drafted for the service. The great corporations may be depended on to organize research and apply its results to the production of increased wealth. But what agencies will organize research and apply the results to Mr. Everyman's welfare?

ELLIOT R. DOWNING
University of Chicago (Emeritus)

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I limit my discussion to science education as it functions below college level, and particularly in secondary schools. For here, I believe, its potential contribution is greatest, since here ends the education of the rank and file of citizens. I do not intend in any way to belittle the college function of training specialists. But the findings of the specialist as a rule affect the world only to the extent that they are acted upon by a wider public that has been convinced of their value.

One of the hardest things science departments may expect to have to do in the future is voluntarily to lose much of their separate identities. Even in their own interests they cannot afford to look first to their own prestige or enrollment or to harbor feelings of competitive jealousy. Instead, they will find it much more to their advantage to cooperate self-forgetfully in the common school task of educating young people (and often adults as well), realizing that each department is a complement, not a rival, of all the others, and that, at this level, advancement of science is after all not their main reason for existence. They may expect, too, to have to relinquish many of their time-honored logical content arrangements and to break down still further all compartmental walls.

In place of so often using artificial problems of purely laboratory or academic interest—"straw men" set up by instructors—the schools will base their work on real problems that appear in the daily associations, locations, and interests of their students. Instead of treating these only incidentally, as heretofore, they will make them the direct centers of attack. This method will soon bring out the need for mastery of basic principles, the study of which will then be purposeful rather than dictated by teacher or textbook. Dependence on a single textbook as authority will disappear, or at any rate diminish in favor of critical use of many sources of information.

Great fundamental principles and relationships rather than multitudinous details will be the major goals of understanding. Some of the more important study areas may have to be worked upon cooperatively by several school departments. One such is conservation of human health and of all natural resources. This involves the constant striving for better use of these resources in aid of human living—elimination of power losses, securing greater output or efficiency, turning wastes to use, creating improved processes and products, developing better consumer understanding and care of materials and appliances. It involves striving for an understanding of the necessity for world cooperation and the inevitability of world interdependence consequent upon air travel and the improvement of communication; of the soundness of regional planning; of the possibilities for betterment of housing and home life; of the potentialities in the genetic improvement of plants and animals and of the human race; of the need for setting our own house in order through doing away with racial and similar discriminations. Other areas of study, of the less applied sort, concerning the nature of the world and of man, will be centered on the objectives of freedom from superstitious dreads and misconceptions, and of creation of a calmer and sounder philosophy of life, and will be approached through presenting the environment in true perspective. The sure but necessarily slow growth in comprehension of the significance of such concepts as the vastness and orderliness of the universe, the inevitability of the cause-effect relationship, the immutability of natural laws, the universality of gradual change, which they so materially affect one's basic outlook upon the world, will in every way be encouraged.

Those characteristics of the scientist often summed up under such terms as scientific method and the scientific attitude will be diligently built up, not in a vacuum, but through being made to permeate all such study as has been described. They are as pertinent to the social studies and to dealing with countless life situations as to the natural sciences. In order to insure their best development it will be found better to undertake fewer learning projects and deal with them thoroughly and broadly than to try to cover conventional knowledge areas more completely and uniformly. The acquisition of added vocational knowledge, independently or through higher work in institutions of learning, and of

broadened views as mature citizens should not be over-difficult for individuals thus trained for independent work and thought.

CARLETON E. PRESTON
University of North Carolina

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Eleven years ago the writer ventured to set forth his "philosophy" of science teaching in a series of articles entitled "The Habit of Scientific Thinking." The gist of the point of view expressed was that the teaching of science can make no greater contribution to the advancement of humanity than that of helping to weave into man's behavior patterns the methods of thinking and attitudes which have led to our scientific discoveries and advance.

In the years which have elapsed since those thoughts appeared in print there have been many occurrences which, while possibly seeming to contradict this point of view, actually strengthen and support it. We are engaged in the greatest armed conflict that the world has ever seen. It is obvious that conflict on such a scale is possible only because of scientific advance and development. However, it is the perversion and misuse of scientific discoveries which makes this conflict possible. It seems self-evident that if man had in his pattern of behavior the attitudes of the true scientist he would never reach the point where he felt impelled to use science for purposes of planned and widespread destruction. A newspaper recently headlined the statement that penicillin will save more lives than war can destroy. Here is at once the glory and tragedy of science. It produces hideously efficient methods of killing human beings and at the same time miraculously effective means for saving life.

What should be science education's greatest contribution in the post-war period? It would seem to be fundamental to train teachers of science in such a way that they will exemplify, in thought and deed, those characteristics which produced the work of the Curies, Pasteur, Darwin, and others. It should further be to train teachers in such a way that they will have the desire above all other purposes in teaching science to develop these same characteristics in their pupils. Too many now teach science who neither really understand nor care about the spirit of science, but who are merely purveyors of information. On the other hand, I believe that most science teachers are fully sympathetic to the accomplishment of this great goal. In teaching numerous classes in science methods, both graduate and undergraduate, I can not recall a single individual who ever expressed himself as being opposed to it, or unduly pessimistic, or hopeless of its eventual accomplishment.

When the war ends there will be a great influx of young men and women, trained to teach, into the ranks of candidates for positions. We should begin now to plan for that time. We should be ready with two procedures basic to supplying the schools with teachers who can and will do the job. The first is selection. Those who are by nature, interest, and training best qualified must be identified and given preference. Second, educational programs for science teachers must give them the training and the tools they need to teach science as a method and a way of thinking rather than merely as a body of organized knowledge.

Finally, it is highly important for those who are in a position to do so to develop instructional materials to be used in teaching scientific methods and attitudes, especially at the junior-high-school level. One such unit for the seventh grade developed recently has been well received wherever it has been tried. Teachers and pupils are ready to do the job if we can only show them the way.

Much could be said about the material benefits of science during the post-war period. In health, transportation, communication, to mention but a few, the advances which are being made will benefit all of us. However, there is little or no encouragement to believe that these material benefits have any noticeable effect on man's approach to the solution of social problems. It is only through the inculcation of the spirit of science that progress will come. It is to be hoped that the post-war period may bring a greater sensitivity to it and a more universal acceptance of our responsibility to meet it through science education.

VICTOR H. NOLL
Michigan State College

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There is growing recognition of the need for reforms directed towards education that is appropriate to the conditions of the times and especially to the ideals of American democracy. The conviction has grown that the various subjects of the curriculum should be brought into closer relationship with one another and that the educational activities made available to young people should be more effective in helping them to understand themselves and the world and to take their full share of responsibility for citizenship. Reports prepared for policy-making bodies lead inescapably to the conclusion that in any revised program of secondary education a prime essential must be a curriculum focused directly on the kinds of competence people need.

The modern world is a world of interrelationships. Out of scientific endeavor have come the materials used in the life of today and the ideas for a new interpretation of the world. These ideas are affecting the whole of life and society. No longer do people consider poverty, disease, and insecurity inevitable. The achievement of the things people need and want are basically dependent on science. The goal of science teaching is to help people realize that science is as much a part of their personal lives as it is of their physical surroundings.

If the aims of science education which find

expression in the writings of scientists and educators are to find expression also in the work of science teachers, they must be expressed as specific objectives. Such objectives may be listed as follows:

1. Good health and physical fitness. There are at least three major diseases whose ravages can be greatly reduced by application of present knowledge: tuberculosis, cancer, and syphilis. The control of these diseases requires the cooperation of sufferers from them and of the sufferers' families. To bring about such cooperation, education is necessary. Here is a real task for science teachers. Another task is the correction of defects such as those which caused rejections from the armed forces.

2. Work experience through participation in the occupations that support the community—in industry, in public service, and in school shops.

3. Comprehension of the nature of production, distribution, and consumption. Such a comprehension involves study of energy transformations, engineering methods, agricultural production, fuels, metals, inorganic materials, chemical industries, housing, and other similar matters.

4. Concern for human beings—their varying potentialities, abilities, interests, outlooks, problems, and responsibilities. Knowledge of growth and development, of physiology and psychology is requisite, as are mutual understanding and respect among people of different groups and awareness of the consequences of actions affecting groups.

5. Knowledge of great changes taking place in the world today—changes, for example, in the efficiency of engines, in production of electricity, in the use of metals, textiles, and plastics, in the productivity of the soil, and in views regarding scarcity and abundance.

6. Ability to select and use the materials that science has made available.

7. Preparation to live in a world in which the ways of life are based more and more on an interpretation of nature; upon the ordered knowledge that men have gained.

SAMUEL RALPH POWERS
Teachers College, Columbia University

The first objective is to provide enough understanding of the place of science in society to enable the great majority that will not be actively engaged in scientific pursuits to collaborate intelligently with those who are, and to be able to criticize or appreciate the effect of science on society. The second objective, which is not entirely distinct, is to give a practical understanding of scientific method, sufficient to be applicable to the problems which the citizen has to face in his individual and social life.—J. D. Bernal, "Science Teaching in General Education." SCIENCE AND SOCIETY, Winter, 1940.

ELLIOT ROWLAND DOWNING, BIOLOGIST AND EDUCATOR

It is with sorrow we report the death of Elliot R. Downing at Williams Bay, Wisconsin on September 10, 1944. Dr. Downing was born in Boston, November 21, 1868. He was graduated from Albion College, Michigan with the degrees of B.S. in 1889 and of M.S. in 1894. His varied early experiences included secondary school teaching, study abroad and study at the University of Chicago leading to the degree of Ph.D. in 1901. He was married to Grace Emma Manning on June 24, 1902.

He was Professor of Biology at Northern State Normal School, Marquette, Michigan, 1901–1911, after which he was called to the University of Chicago as Assistant Professor of Natural Science. He was promoted to Associate Professor in 1913 and continued in this position until his retirement in 1934. He has been an active contributor to the advancement of education in science not only through his work at the University but also through other agencies. He was President of Michigan State Non-Game Bird Commission, 1907–1911, and Editor of *Nature Study Review*, 1911–17. He was a fellow in the American Association for the Advancement of Science and a member of several professional organizations. He was a charter member of the National Association for Research in Science Teaching and was President from 1930 to 1932.

His writings include *Elementary Eugenics; A Naturalist in the Great Lakes Region; Our Living World; Our Physical World; Teaching Science in the Schools; Science in the Service of Health; Introduction to the Teaching of Science;* and (with Veva M. McAtee) *Living Things and You.* He is survived by Mrs. Downing, three children and five grandchildren.

On account of his frequent attendance and active participation in meetings, Dr. Downing has been for many years a familiar figure at gatherings of scientists and of science teachers. He will be sorely missed.

SAMUEL RALPH POWERS

EDITORIALS

REPORT ON THE QUESTIONNAIRE

The questionnaire that was published in the April-May issue of SCIENCE EDUCATION elicited 94 returns, many of them accompanied by letters containing valuable suggestions. The editors wish to thank all who responded and to assure them that their replies are being used as a basis for developing the editorial policy of the journal.

The first question concerned the departments proposed by the Committee on Publication. Of these, all save one were approved by more than 88 per cent of the respondents. The suggested department, "The Science Teacher's Heritage," met with approval from only 64 per cent of those answering the questionnaire.

Acting upon the information thus obtained, the Committee plans to present major articles in the areas of "Science Today," and "Science in the Community"; to publish brief papers under the general heading, "Teaching Reports and Suggestions"; to maintain and develop the "Reviews and Abstracts" department, and to inaugurate departments entitled "Research in Science Teaching" and "Significant Trends in Education." The new departments will appear in the next issue of the journal. Dr. Francis D. Curtis, Professor of Secondary Education, University of Michigan, has agreed to act as editor of the department of Research in Science Teaching. The department of Significant Trends in Education will be edited by Dr. R. Will Burnett, Assistant Professor of Education, Stanford University.

Two items on the questionnaire dealt specifically with the matter of Book Reviews. While there was overwhelming agreement as to the value of reviews, there was considerable difference of opinion as to the areas that should be covered. The majority of the respondents favored reviewing textbooks for elementary and secondary schools and interpretations of science for teachers; only a few wanted reviews of college textbooks and books on education. There was almost an even division on the question of the nature of the book reviews: 50 per cent favored critical and detailed reviews; 57 per cent wanted brief notations. Some people, as the percentages show, asked for both sorts of reviews; to provide both seems to the Committee, too, to be the best procedure.

The final question dealt with the publication schedule of the journal. Here, too, there were differences of opinion. Sixty-two per cent of the readers, however, considered the present publication dates satisfactory and thus emboldened the Committee to continue this schedule for the time being.

The next number of SCIENCE EDUCATION to appear will be Number 1 of Volume 29, and will be published in February, 1945. It will be issued under the general editorship of Dr. Samuel Ralph Powers, Head of the Department of Teaching of Natural Sciences, Teachers College, Columbia University.

—E.M.M.

SIGNIFICANT TRENDS IN EDUCATION

The good science teacher has always accepted and discharged his responsibility in keeping abreast of scientific progress. The chemistry teacher today is going beyond his textbook to a consideration of the chemistry of thermosets and thermoplastics and to a vision of the world ahead. The physics teacher already seeks to incorporate in his work more fully the story of radar and other wartime advances in physical engineering. The biology teacher is enthusiastic about DDT, penicillin, and similar important incidents in the advance of biological knowledge.

But every science teacher recognizes that his is a profession in which mastery is compounded of more than technical knowledge and proficiency of a scientific order. Teaching proficiency requires a fundamental grasp of the trends of the times, recognition of the basic problems and issues of modern life, understanding of the learning process, and the professional ability to select and organize content and experiences from the fields of science to provide for individual development of young people for competence and happiness in modern living.

The science teacher has an important role to play in American education. But he is one of a team composed of certain non-school research and educational organizations and of educational research workers, administrators, and teachers of disciplines other than science. Perhaps more than he sometimes realizes, what he teaches and the way in which he teaches, are influenced and will continue to be modified by the broad issues and trends of the day and the thinking and activities of others of this professional educational team.

Three examples—varying in scope and significance — should sufficiently underwrite this point. The double laboratory period of the laboratory sciences in the schools of San Francisco, California, was abandoned some two years back in favor of a single period. The relative advantages of either plan are debatable. The important point is that the change was made on the basis of broad educational policy and administrative expedience; and without the mature deliberation of the science teachers of that city. Not a big point, perhaps, but interesting as it reflects the common image of science teachers alert and capable in their own fields but insufficiently informed

to evaluate and contribute effectively to the educational policy which affects them and the success of their work.

A second example is the whole range of wartime adjustments in science teaching in which science teachers as a whole had little part to play. Pre-induction training courses, pre-flight aeronautics, and adjustments in traditional programs of science courses were made on premises which, to many if not most science teachers, have been totally unclear. The fact that a few science teachers and representatives of their organizations were instrumental in some of these wartime modifications does not alter the fact that the majority of science teachers found it necessary to accept rather blindly such modifications as were recommended under prestige auspices or required by their administrators.

A third example is the historical record of changes in objectives and points of view in science teaching; a record which discloses retrospectively that which may confidently be anticipated for the future: that science teaching is inextricably involved in the policy making and trends of any educational period. Science entered the curricula of western schools in part to support, through its interpretation of a mechanical universe of order and rationality, the deistic conception of the didactic writers of the time. The science teachers taught in this mold. With the advance of the faculty school of psychology in the nineteenth century the aims of science teaching, if not wholly the methods, were modified in rather short order. For the past decade, and continuing at present, the trend toward a newer conception of a liberal education—commonly called general education, as opposed to an older and aristocratic view of liberal education—has been modifying science education throughout the country. An examination of modern textbooks, courses of study, and professional writings will substantiate the statement. It is unnecessary to question the soundness of this or other basic philosophies of education. The important thing is that busy science teachers, by and large, have not had opportunities to be participants in or even *informed* reactors to these formulations of policy. A few leaders in science education have, it is true, always been instrumental in the development of educational policy. But the one who really counts—the teacher in the classroom—has found it difficult to understand the forces that have shaped and are shaping the broad alignments of his work.

This has not been a moral fault of the science-trained teacher. The job of keeping up with even one aspect of a field of science is prodigious. Furthermore the science-trained teacher has become accustomed to the characteristic specialized writings of science—writings more largely factual than theoretical which have a succinct and precise method of expression of their own. To study the voluminous and seemingly vague and wordy meanderings of the educational philosophers and the reports of policy committees has appeared to be a fruitless if not an impossible task to many busy science teachers. But the fault has been practical, if not moral. Until large numbers of science teachers are able to react in concert to policy as it is formulated, until they participate in and *initiate* the formulation of policy which affects them, they will remain in the back seat of the vehicle of educational progress.

Hence the need for a department of SCIENCE EDUCATION devoted to reporting and interpreting significant trends in educational policy as proposed by the major formulators of such policy. It will, of course, be impossible to discuss all the reports prepared by national and regional educational and non-educational organizations. But an attempt will be made to present a distillation of those which appear most significant, and to interpret such statements in terms of their implications for science teachers. Although the major part of the department will be devoted to

reports as they become available, occasionally space will be given to reports which are not strictly contemporary when such reports seem to be exercising major influence in science education or to be capable of such influence.

The effectiveness of these interpretations and reports depends upon the reactions of science teachers in secondary schools, classroom teachers in elementary and junior high schools, supervisors and heads of departments of science, teachers in normal schools and teachers colleges or education departments. It is our hope that these pages may be of assistance to the general curriculum worker, supervisor, or administrator who may come to examinne them for interpretations of educational policy and recommendations concerning it from professional workers in science.

—R.W.B.

PLANS FOR THE RESEARCH DEPARTMENT

Present plans for the Research Department of SCIENCE EDUCATION include the following features:

1. Digests of research investigations of the various aspects of the teaching of science, presented in a format similar to that used in the three volumes of *Digests of Investigations in the Teaching of Science*. These digests will be chiefly those of unpublished studies, especially dissertations.

2. Reports of important research studies under way in various centers.

3. Authoritative summaries of progress made through research toward the solution of certain important problems or toward the clarifying of certain basic ideas or concepts. For example, there have been many efforts to clarify the concept of "scientific principle" and to make available authoritative lists of such principles; for the next issue, Dr. W. Edgar Martin is preparing a historical summary of the important research that has been carried on in this area since Dr. Elliot R. Downing's pioneer work.

4. Interpretations of the practical implications of selected investigations or of groups of investigations dealing with areas of instruction, such as the uses and values of different types of visual and auditory aids and the relative values of teaching methods.

These plans are tentative. Suggestions for making this department useful to classroom teachers as well as to research workers will be welcomed.

—F.D.C.

PRELIMINARY ANNOUNCEMENT

Seminar on Reading Disabilities, January 29 to February 2, 1945

Conference on Reading Instruction, June 26 to June 29, 1945

The Reading Clinic Staff of the School of Education, The Pennsylvania State College, State College, Pennsylvania, is sponsoring two important meetings on reading problems during 1945.

The Annual Seminar on Reading Disabilities will be held from January 29 to February 2, 1945. Demonstrations and discussions on a differentiated program for analyzing and typing, or classifying, reading disabilities will be conducted by the Staff of the Reading Analysis Unit of the Reading Clinic. Remedial techniques will be demonstrated and discussed by the staff of the Reading Clinic Laboratory School. A number of visiting speakers and demonstrators have been included. The program has been planned to interest remedial teachers, school psychologists, speech teachers, neurologists, otologists, and vision specialists.

From June 26 to June 29, 1945, the Reading Clinic Staff will conduct the Annual Conference on Reading Instruction. This Conference deals with classroom problems. The activities are differentiated for elementary and secondary teachers, college teachers, special class teachers, speech teachers, and school psychologists.

Copies of the program and information on transportation schedules may be obtained from Miss Betty J. Haugh, Reading Clinic Secretary. Those desiring college credit, especially Graduate School credit, for the seminar should register in advance with the Director of the Reading Clinic.

EMMETT A. BETTS
Research Professor and Director of the Reading Clinic, School of Education, The Pennsylvania State College

ABSTRACTS

BLICK, DAVID J., AND ANDREWS, RAYMOND R. "A Study of the Achievement in General Chemistry in the A. S. T. Program." *Journal of Chemical Education*, 21: 236–238, 242. May, 1944.

This study had as its major problem the determination of the degree of mastery of general chemistry by students in the Basic Engineering Curriculum at the University of Connecticut. To obtain a comparison of the achievements of this group with regular college students, the Cooperative General Chemistry Test for College Students, Form 1942, was given. The achievement of the average trainee in A.S.T.P. was found to be slightly higher than that of the average college students in first-year college chemistry.

—C.M.P.

PAYNE-GAPOSCHKIN, CECILIA. "Marginalia." *American Scientist* 32: 222–226. July, 1944.

This article summarizes the latest research findings relative to the cosmic time scale and the genesis of the chemical elements. Not so long ago Jeans stated that stellar evidence demanded far greater ages for the stars than that assigned to the earth (between 1,500 and 5,000 million years). He suggested an order of 10^{13} years. But since 1935 opinion has turned toward an estimate of the age of the stars as approximately 2,000 million years and as a maximum probably not over ten times this value.

Two methods of approach to the genesis of the chemical elements have received attention. The first supposes the elements to have been produced by equilibrium reactions at high temperatures; the second considers the possibility of their genesis by nuclear fission. Galactic nebulae, whether diffuse or in envelopes, appear to have the same composition.

—C.M.P.

TAYLOR, NORMAN. "Come and Expel the Green Pain." *Scientific Monthly* 58: 176–184, March 1944.

The title is part of a ritual from an ancient Aztec plant cult. The chief plants venerated are a species of cactus, the peyotl (or peyote or mescal button), and the ololiuqui. They are used not only for divination in the secret rites but as narcotics and as medicine. Of the latter plant the seeds are used, usually by a solitary devotee; in the former both the root and small mushroom-shaped knobs on the plant are chewed, largely by ceremonial groups.

The alkaloids in them produce a form of intoxication characterized by hallucinations—a flight from reality which the Mexican Indians consider to be a form of indwelling of divinity! A kind of hypnotic sleep or coma is later induced.

The botanist-author has here a fascinating tale of an unusual plant-use.

—M.E.O.

CHAMPION, F. J. "Wood Comes of Age." *Scientific Monthly* 58: 195–206, March, 1944.

Man has used wood in many ways since ancient times. Now, although meeting competition from metals, plastics, ceramics, glass, and other products, it will be available in a great variety of improved forms as the result of research in many university and industrial centers and, especially, in the Forest Products Laboratory at Madison, Wisconsin. These new developments include: moisture-resistant plywood, useful in mass-production and prefabricated housing, industrial, and farm structures; greatly strengthened timber joints and laminated arch beams, making possible great roof span in gymnasiums, hangars, and similar buildings and also making possible wood radio towers as high as 300 to 400 feet; "stressed-skin" panels and "bag-molding" units have been used in walls, small boat hulls, aircraft parts, and the like; "impreg"—a resin-treated laminated wood which is moisture resistant to a high degree; "compreg"—hot-pressed, resin-treated sheets of greater density and surface hardness; "hydroxylin"—a low-cost, general purpose plastic made in two forms, molding powder and laminating sheets; "papreg"—plastic-like paper laminate of high durability and strength; and "uralloy"—urea-plasticized wood. Other "new wood derivatives and wood processing methods, not immediately applicable to war needs, lie dormant in chemists' notebooks."

—M. E. Oakes.

MOULTON, F. R. "Forty Years of Education." *A. A. A. S. Bulletin* 3: 49–50. July, 1944.

This article discusses the tremendous changes in elementary, secondary, and college education during the period 1900–1940. The average number of days of the elementary and secondary school year has increased from 144 to 175, the average salary of teachers from $325 to $1,441, the total enrollment in secondary school from 696,000 to 7,113,000, the number graduated from secondary schools from 95,000 to 1,288,000. The total college enrollment has increased from 238,000 to 1,493,000.

—C.M.P.

ALEXANDER, GORDON (University of Colorado). "The College Curriculum in Wartime and Introductory Courses in Biology." *Science* n.s. 99: 78–80, January 28, 1944, and

SHULL, C. A. (University of Chicago). "General Biology." *Science* n.s. 99: 199, March 10, 1944.

Report Number 15, "Adjustment of the college curriculum to wartime conditions and needs," issued by the U. S. Office of Education, seems to have fanned to flame an issue which was aglow at least a quarter century ago. The question is: Is there such a thing as General Biology; or are there only Botany and Zoology? The old quip: "General Biology is either botany

taught by a zoologist or zoology taught by a botanist" is quoted in part.

The Committee which wrote the Report concludes that general biology courses are not satisfactory for beginning students and recommends separate courses in botany and zoology, either one of which is better.

Professor Anderson points out that (1) general biology is successfully taught in many institutions; (2) the weaknesses of this course were more clearly and objectively stated in an article in *Science* in 1919; (3) biologists are not all, of necessity, either botanists or zoologists.

Professor Shull states simply that (1) "courses in general biology [have] been a fraud against the student"; (2) to "concoct" a correlative course in physical science would be no improvement (put as a rhetorical question); (3) "botany is a unified subject, coordinate with chemistry"; (4) ditto for zoology; and (5) "general biologists have been fooling themselves and the world of education far too long."

This whole discussion—or should one say dissension?—suggests several speculations: Wouldn't it all lead an opponent of science to gloat? A student of propaganda would notice a number of "loaded" or emotionally toned words, e.g. "successful," "fraud," "concoction," "fooling." When it is asserted that this course or that is *best*, one wonders, "best" for whom or for what?

—M.E.O.

BOOK REVIEWS

BRUCE, GUY V. "Children's Play at Science Series": Book III. *Magnetism and Electricity*, 86 p. 1939. Book IV. *Sound, Light and Color*, 87 p. 1943. Newark, N. J.: Guy V. Bruce, State Teachers College, $1.15 each.

The first two volumes of this series, *World of Air and Water*, and *Heat, Fire and Fuels* were reviewed in the January 1939 issue of SCIENCE EDUCATION. At that time the reviewer, the late Dr. Underhill, stated: "Do not let the title of this series mislead. It may be 'play' in the sense that the activities described will be carried on with enthusiasm and enjoyment by elementary school children, but it is real science. . . The reviewer feels that this series should prove one of the most valuable aids so far published for the average classroom teacher who wishes to carry on a modern program of elementary science." These comments hold as true regarding the above two listed volumes. Each volume contains 51 experiments suitable for all grades. The directions are brief and simple. The materials and apparatus are mostly of the home and ten-cent store variety, or readily procurable from most school science departments. Accompanying sketches facilitate an understanding of the experiments described. The experiments are classified, adding to the usefulness of the volumes. General science teachers will find the volumes a rich source of pupil activities and class demonstrations.

—C.M.P.

MCKOWN, HARRY C. *Fools and Foolishness.* Topeka, Kansas: School Activities Publishing Company, 1943. 263 p. $2.00.

Fools and Foolishness is an entertaining and thoughtful presentation of the thesis that substantial contributions to our present civilization have been made by heroes whose contemporaries called them fools. As a general rule, society neither welcomes nor encourages change. Every important scientific advance has been resisted by the learned as well as by the illiterate.

Fools and Foolishness examines the prejudices against change in practically every field of human endeavor. There are many interesting and amusing illustrations of reactionary opposition to new ideas in communication; industry; land, water, and air transportation; agriculture; art; sports and recreation; and so forth. Yes, "everyone is a little bit queer, but thou and me, and thou art the least bit queer."

—C.M.P.

JEANS, SIR JAMES. *The Universe Around Us.* New York: The Macmillan Company, 1944. 297 p. $3.75.

The Universe Around Us was first published in 1929. It immediately became a best seller and nearly three-quarters of a million copies have been sold. Translated into thirteen languages, it has brought the science of astronomy down to the level of the educated layman. *The Universe Around Us* has now been completely rewritten, expanded, and brought up to date. The appealing style and skilled use of understandable analogies are supplemented with many excellent photographs and diagrams.

Characteristics of the style and conclusions of Jeans are indicated in the following quotations:

"Empty Waterloo Station of everything except six specks of dust and it is still more crowded with dust than space is with stars."

"Take a postage stamp and stick it to a penny. Now climb Cleopatra's needle and lay the penny flat postage stamp uppermost, on top of the obelisk. The height of the whole structure may be taken to represent the time that has elapsed since the earth was born. On this scale, the thickness of the penny and postage stamp together represents the time man has lived on earth. The thickness of the postage stamp represents the time he has been civilized

and the thickness of the penny represents the time he lived in an uncivilized state."

"The universe appears to be increasing its dimensions 1 per cent in every twenty million years."

"The universe consists in the main not of stars but of desolate emptiness—inconceivably vast stretches of desert space in which the presence of a star is a rare and exceptional event."

"Calculation shows that any star may expect to move for something in the order of a million, million, million years before colliding with a second star."

"The 10,000 million years which seems a possible future for existence of life on earth is more than three times the past age of the earth and more than 10,000 times the period through which humanity has so far existed on earth."

"As inhabitants of a civilized earth, we are living at the very beginning of time."

—C.M.P.

URBAN, JOHN. *Behavior Changes Resulting from a Study of Communicable Diseases.* New York: Bureau of Publications, Teachers College, Columbia University, 1943. viii + 110 p. $1.85.

The topic "Education Changes People" has often been used in commencement addresses, sometimes without much factual support. We believe the thesis but can't always prove it. Also, it is generally believed that one's attitudes influence his behavior. If that is true, and if attitudes can be changed, there would be consequent changes in behavior. The book of this review consists of a report of a careful experiment to find out whether one small unit of teaching material did make any measurable change in a class of high school pupils.

The problem as stated was: Can the study of communicable diseases by high school general biology pupils result in desirable changes in the overt behavior related to the control of these diseases? Fifteen serious diseases were listed. Most of the list have been subjects of effective scientific research in recent decades. Controls or cures are now known for most of them, and there exist abundant data for use as instructional material. It is possible to organize interesting factual foundations for study, as well as to give explicit instructions regarding avoidance of some of the list of diseases, or cure, if acquired.

A preliminary check was given to one hundred ten pupils. This disclosed not les than twenty-three pupil habits or behaviors by means of which one or more of the diseases might be acquired. Some pupils displayed several of these habits. These habits showed the need for changes in behavior, and were kept in mind in formulating the teaching material and in devising checks and controls of teaching results. The habits were determined by pupil responses to tests, by observation and by individual conferences.

In the teaching, two classes used as controls studied a unit of work not closely related to communicable diseases. With the other pupils the specially prepared unit was used. Pupils were of "mixed age, intelligence quotient, achievement, and background, but the experimental group and the control group were fundamentally similar." They had studied essentially the same science material up to the time of this experiment. The period of the experimental study, including information tests, was six weeks in length. In addition to the tests during and at the close of the experiment, other tests were given twelve weeks later. Numerous source materials besides the special unit were available. The book includes full details of the teaching unit, the tests used, and the statistical analysis of results. Documentation is abundant.

The conclusions drawn from the study are abbreviated in this review. The experimental group made much larger information gains than the control group. In observed overt behavior the experimental group "made great gains which were not matched by the control group." The attitude changes persisted more fully at the end of the twelve weeks after-period than did the items of information. While information items were correlated with intelligence, "there was little, if any, correlation between intelligence and the behaviors studied." Scores on information were not significantly correlated with various behaviors. It is therefore claimed "that changes in behavior can be brought about as a result of learning experiences." That is, one may again conclude that specific types of education do make specific changes in people.

—OTIS W. CALDWELL

MORGAN, ALFRED. *First Principles of Radio Communication.* New York: D. Appleton-Century Company, 1943. 366 p. $3.00.

The author has written a quite complete, simple, practical course in the principles of radio communication. Beginning with the basic principles of electricity, upon which an understanding of radio depends, the more complex steps are logically and simply developed. Many important points which are often obscure in texts are here made clear. The author has found it necessary to use very little mathematics. Nearly 200 diagrams aid in making the textual material more readable.

The author is a radio engineer with more than twenty years experience, and a writer of more than a score of popular science books, several of which have been in the field of radio.

First Principles of Radio Communication is recommended for high school students and adults interested in obtaining a better understanding of radio. General science and physics teachers will find it useful.

—C.M.P.

SHIELDS, BERT A. *Principles of Air Navigation.* New York: McGraw-Hill Book Company, 1943. 451 p. $2.20.

This is the best book on air navigation that this reviewer has seen. Teachers of high school pre-induction aviation courses, the boys in those courses, and the air corps students now taking pre-flight training would profit from having available this simply written, well illustrated, and practical treatise. The book explains maps and charts, computing and calculating devices, and various kinds of navigation. It is worthy of extensive use. —C.M.P.

MUÑOZ, F. J., AND CHARIPPER, H. A. *The Microscope and Its Use.* Brooklyn: Chemical Publishing Company, Inc., 1943. 334 p. $2.50.

Microscopes often become unfit for use because of improper handling. One must know how to use a microscope and how to take care of it. This book gives practical instructions in clear, simple language.

The development of the microscope is traced from the simple convex lens of antiquity to the modern microscope. Stereoscopic, metallurgical, and polarizing microscopes are discussed fully. There are over a hundred photographs and drawings. A glossary of terms used in connection with microscopes is found in the last few pages.

One of the authors is a microscope consultant, the other a professor of biology. The book will prove valuable to anyone who uses microscopes.

—Roy V. Maneval.

MALISOFF, WILLIAM M. *Dictionary of Biochemistry and Related Subjects.* New York: Philosophical Library, Inc., 1943. 579 p. $7.50.

The author has collaborated with forty-six leaders in special fields of science to produce a very helpful pioneer dictionary for the specialist or layman. It includes terms now bordering on obsolescence as well as newly-coined ones. It is really more than a dictionary or glossary in the ordinary sense. Some topics are treated at fair length: for example, teeth, hair, biochemistry of psychiatry, phosphate bond energy, and bacteriophage run to several pages for each discussion. Frequent references to more complete treatment of topics increase the usefulness of this comprehensive volume.

—W.G.W.

LOBECK, A. K., AND TELLINGTON, W. J. *Military Maps and Air Photography.* New York: McGraw-Hill Book Company, 1944. 256 p. $3.50.

At no time in the world's history have map making and map reading been so important as they are today. This book with its 8" x 11" pages has drawings and halftones that help to explain the different conditions the map reader will meet. Mastery of the material in this text will make one expert in reading maps, understanding conventional signs and symbols, and interpreting contour groupings automatically. The book has parts entitled: Basic Map Reading, Elementary Problems and Methods, Topographic Forms, Advanced Map Reading, Landscape Types, Air Photographs, and Problems.

—W.G.W.

GAMOW, GEORGE. *Mr. Tompkins Explores the Atom.* New York: The Macmillan Company, 1944. 97 p. $2.00.

This book is a sequel to *Mr. Tompkins in Wonderland.* The author is known among scientists for his pioneering work on the theory of atomic nuclei; but these books on physics and mathematics are written in a popular and humorous style. The reader of this new story of science will, with Mr. Tompkins and his wife, become acquainted with the world inside the atom and the "gay tribe of electrons." The book is cleverly illustrated by the author.

—Greta Oppe.

CARLISLE, N. V., AND LATHAM, F. B. *Miracles Ahead.* New York: The Macmillan Company, 1944. 288 p. $2.75.

In the post-war world there will be many devices unknown in pre-war years. Some of these will be immediately available; others may not be perfected for some time. Among the advances discussed in *Miracles Ahead* are those having to do with prefabricated houses, air-conditioning, cold storage, heating, lighting, and sound-proofing; with automobiles and airplanes, radar and television; with plastics, textiles, synthetic "rubber," glass, and alloys; with new agricultural methods and products, dietary changes, preventive medicine, and progress in conquering diseases; and finally with new and cheaper sources of energy.

Miracles Ahead is appropriate supplementary reading for high school science classes.

—C.M.P.

GRUENBERG, BENJAMIN C., AND BINGHAM, N. ELDRED. *Biology and Man* Boston: Ginn and Company, 1944. 719 p. $2.24.

This high school biology textbook centers attention on man. Every unit stresses the relation to man of the material presented. The units are: (1) What Is Life? (2) Under What Conditions Can We Live? (3) How Do Living Things Keep Alive? (4) How Do the Parts of an Organism Work Together? (5) How Do Living Things Originate? (6) How Did Life Begin? (7) Why Cannot Plants and Animals Live Forever? (8) What Are the Uses of Biology? There are numerous tables, charts, and pictures. These seem to have been most carefully selected and are pertinent to the discussion at hand. The pictures are all clear-cut.

The authors' rich experience in secondary biology teaching and thinking are in evidence throughout the book. Dr. Gruenberg was for-

merly chairman of the biology departments of the Commercial and Julia Richmond High Schools in New York City and is now a Consultant with the Social Security Board. Dr. Bingham has taught science in the Horace Mann—Lincoln School of Teachers College, Columbia University, and is now at Temple University.

—C.M.P.

JORDAN, PASCUAL. *Physics of the 20th Century.* New York: Philosophical Library, 1944. 185 p. $4.00.

This book gives a clear picture of the growth of physics through a survey and critical analysis of the various theories from the early Greek philosophers to the present day of modern physics. Excellent treatment in non-mathematical language.

—W.G.W.

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BOOKS RECEIVED

BENNET, H., Editor. *The Chemical Formulary, Volume VI.* Chemical Publishing Company, Inc., Brooklyn, 1943. 636 p. $6.00.

BLACKWOOD, OSWALD. *General Physics.* John Wiley and Sons, Inc., New York, 1943. 622 p. $3.75.

BOWLEY, AGATHA. *Guiding the Normal Child.* Philosophical Library, Inc., New York, 1943. 168 p. $3.00.

BROWNLEE, FULLER, HANCOCK, SOHON, AND WHITSIT. *Elements of Chemistry.* Allyn and Bacon, Boston, 1943. 684 p. $1.44.

BUELL, MAHLON; SCHULER, FREDERICK; TEETERS, W. R. *Physics Workbook.* J. B. Lippincott Company, Chicago, 1944. 378 p. $1.12.

BURNHAM, R. W. *Mathematics for Machinists.* John Wiley and Sons, Inc., New York, 1943. 253 p. $1.50.

CARPENTER, H. A., BAILEY, G. A. AND TUTTLE, M. E. *Adventures in Science with Jack and Jill.* Allyn and Bacon, Boston, 1942. 314 p. $0.75.

———. *Adventures in Science with Ruth and Jim.* Allyn and Bacon, Boston, 1942. 407 p. $0.90.

COWDRY, E. V. *Microscopic Technique in Biology and Medicine.* Williams and Wilkins Company, Baltimore, 1943. 206 p. $4.00.

CRISP, K. B. *Health for You.* J. B. Lippincott Company, Philadelphia, 1944. 576 p.

DAUS, P. H., GLEASON, J. M. AND WHYBURN, WILLIAM. *Basic Mathematics for War and Industry.* The Macmillan Company, New York, 1944. 277 p. $2.00.

DITMARS, R. L. AND CARTER, HELENE. *Twenty Little Pets from Everywhere.* Julian Messner, Inc., New York, 1943. 64 p. $2.50.

DUNN, MARSHALL AND MORRISETT, LLOYD. *Machines for America; Power for America; Wings for America.* World Book Company, Yonkers-on-Hudson, New York, 1943. 244 p. $1.00.

GRANT, J. C. B. *An Atlas of Anatomy in Two Volumes, Vol. I.* Williams and Wilkins, Baltimore, 1943. 214 p. $5.00.

GRANT, JULIUS. *Hackh's Chemical Dictionary.* The Blakiston Company, Philadelphia, 1944. 925 p. $12.00.

GRAUBARD, MARK. *Man's Food: Its Rhyme or Reason.* The Macmillan Company, New York, 1943. 213 p. $2.50.

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